FRDA Report 132

Forest Vegetation Management Research Strategy for the Southern Interior, British Columbia

by

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EXECUTIVE SUMMARY

In the southern interior of British Columbia, the FRDA vegetation management research program has been organized by broad climatic units and vegetation complexes. This approach has been useful for organizing problem-specific and site-specific research. However, a framework is now required to organize the result of these projects into tools which have general field application, and to coordinate future research.

The purpose of this report is to identify key research needs in the southern Interior and to outline a framework for synthesizing the research results into operationally useful tools. This report was prepared following a review of available documents, field tours in the southern Interior, and discussions with field and research staff. It is intended that this strategy will form the basis for a long-term program of vegetation management research in the southern Interior.

To identify key research needs, a questionnaire was distributed to forest, range and wildlife managers and forestry researchers working in, or doing work relevant to, the southern Interior. Responses were received from 88 individuals during November and December of 1987. At the time of this survey, respondents clearly felt that results of vegetation management research were not being fully applied or effectively communicated. Operationally useful tools for assessing interference from non-crop vegetation (i.e., "competition indexes"), for predicting vegetation development and brush hazard, and for selecting treatment options were identified as priority items. The ESSF, ICH, and IDF biogeoclimatic zones were identified as key areas requiring research. The mixed shrub - herb and aspen and mixed hardwood complexes were identified as having the highest priority for further research.

According to respondents, field trips, demonstrations, workshops, and training sessions were preferred over printed documents and technical conferences as a medium for learning about research results. Field guides and technical experts were the most popular "decision support tools."

Research is under way or has been completed in 9 of the 14 vegetation complexes which occur in the southern Interior. However, most of these projects have narrowly defined objectives and deal with only a limited range of sites. While of potential relevance to other research sites with identical conditions, such research tends to be limited in its general application. Operational field staff require generally applicable tools which will assist them with making prescriptions. The development of these decision support tools must therefore be a key component in future vegetation management research.

Decision support tools are needed in four broad areas:

1. for assessing the present or future impact of non-crop vegetation on crop species, and for identifying the need for and potential benefits of vegetation management;
2. for predicting the future development of non-crop vegetation and potential "brush hazard",
3. for selecting appropriate and effective methods for vegetation control; and
4. for evaluating both the short-term and long-term ecological, environmental, and economic consequences of alternative management strategies and methods.

Developing these tools requires a systematic approach to problem solving. All future research should therefore be conducted within an ecosystems framework and within the context of rotation-length silvicultural systems. Computer-based tools, such as simulation models and expert systems, should be used to synthesize available information, and to make predictions based on this information. All of these tools will assist foresters in identifying critical information gaps and research needs, and in applying research results.

Specific recommendations for vegetation management research in the southern Interior are:

1. That vegetation management research be organized within an overall research framework that has as its goal the development of operational vegetation management tools (decision support tools).
2. That these tools include field assessment, prediction and management guides, a computerized "expert system" to provide a more detailed evaluation of field decisions, and computer simulation

models with which long-term predictions and economic assessments can be made, and the results of diverse field research projects integrated.

3. That research protocols be developed to ensure that existing and new research projects provide the necessary data bases for the calibration and evaluation of these decision support tools.
4. That new research projects be initiated to provide data and knowledge needed for developing the decision support tools.
5. That a system of long-term sample plots be established to provide empirical data on the long-term consequences of vegetation management.
6. That many of the existing research projects be replicated on other problem vegetation complexes not yet adequately studied.
7. That a major and sustained effort be made to transfer the knowledge and management tools developed by this research program to the operational forest managers for whom it is intended. This will involve a sustained program of workshops and training sessions, and the development of a variety of communication packages (manuals, tape-slide shows, videos, and computer-based management gaming tools).
8. That the vegetation management research program and vegetation management decisions be integrated into the overall stand-level, rotation-length, silvicultural systems of which they are but a component. This will require the development and use of ecosystem-level, rotation-length management simulation models.
9. That vegetation management decisions be made for the whole forest (timber supply area) as well as for the stand level. This suggests that the stand-level decision support systems referred to in this report be integrated with a Geographical Information System or some other whole-forest model.
10. That vegetation management needs and the goals of vegetation management research be reviewed periodically to ensure that any research strategy adopted in the southern Interior is still relevant and focussed on the production of management tools that are needed at the time.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY iii

ACKNOWLEDGEMENTS v

SECTION 1: THE NEED FOR AN OVERALL VEGETATION MANAGEMENT STRATEGY 1

1.1 Origin and Scope of the Report 1

1.2 Objectives of the Report 1

1.3 Conceptual Approach Adopted in Developing the Strategy 2

SECTION 2: PAST AND PRESENT OPINIONS CONCERNING VEGETATION MANAGEMENT PROBLEMS AND RESEARCH NEEDS 5

2.1 Reports on Vegetation Management in British Columbia 5
- 2.1.1 The Conard report 5
- 2.1.2 The Boateng report 6
- 2.1.3 The Sutton review 6
- 2.1.4 The Butt report 6
- 2.1.5 The Butt-Bancroft report 7
- 2.1.6 Reports relating to the herbicide option in vegetation management 8
- 2.1.7 Research protocols 8
- 2.1.8 Scoping and brainstorming sessions 8

2.2 Summary 8

SECTION 3: A SURVEY OF CURRENT OPINIONS REGARDING VEGETATION MANAGEMENT AND RESEARCH NEEDS 11

3.1 Questionnaire Responses 11

3.2 Summary 15

SECTION 4: EARLY SERAL VEGETATION IN THE SOUTHERN INTERIOR AND THE NATURE OF INTERACTIONS BETWEEN CROP AND NON-CROP VEGETATION 17

4.1 Factors Influencing the Pattern and Rate of Secondary Succession 18

4.2 Predicting Secondary Succession 19

4.3 Interactions Between Crop and Non-Crop Vegetation 20
- 4.3.1 Beneficial aspects of vegetation cover 20
- 4.3.2 Interference 20
- 4.3.3 Other causes of regeneration failure 22
- 4.3.4 Indices of competition and interference 22

4.4 Summary 22

SECTION 5: CURRENT STATUS OF VEGETATION MANAGEMENT RESEARCH AND INFORMATION IN THE SOUTHERN INTERIOR 25

5.1 Current FRDA Vegetation Management Research Activities in the Southern Interior 25
- 5.1.1 Assessment 25
- 5.1.2 Prediction 26
- 5.1.3 Management 27

5.1.4 Environmental impacts 27
5.1.5 Development of decision support tools 27

5.2 Research Needs 28
5.2.1 Assessment 28
5.2.2 Prediction 28
5.2.3 Management 29
5.2.4 Impacts of treatment 29
5.2.5 Decision support tools 29

5.3 Summary 29

SECTION 6: A FRAMEWORK FOR VEGETATION MANAGEMENT RESEARCH 31

6.1 A Framework for Vegetation Management Research 31
6.1.1 Ecosystem framework 32
6.1.2 Vegetation management as a component of rotation-length silvicultural systems 32

6.2 Research Protocols for Vegetation Management 32
6.2.1 Research related to the assessment of vegetation management problems 33
6.2.2 Research related to the prediction of vegetation management problems 34

6.3 The Need for Tools of Integration and Synthesis 35

6.4 Summary 36

SECTION 7: A VEGETATION MANAGEMENT RESEARCH STRATEGY FOR THE SOUTHERN INTERIOR 37

7.1 Objectives of the Research Strategy 37
7.1.1 Overall (strategic) objectives 37
7.1.2 Specific (tactical) objectives 38

7.2 A Strategy for Vegetation Management Research 38
7.2.1 Expansion and modification of existing projects 39
7.2.2 New projects 39

7.3 Concluding Statement 40

SECTION 8: IMPLEMENTATION OF RESEARCH RESULTS IN OPERATIONAL VEGETATION MANAGEMENT: A STRATEGY FOR "TECHNOLOGY TRANSFER" 41

8.1 Strategy for Technology Transfer 41

8.2 Concluding Statement 41

SECTION 9: CONCLUSIONS AND IMPLEMENTATION 43

9.1 Recommendations 43

9.2 Implementation of the Recommendations 44

POSTSCRIPT 46

REFERENCES 47

APPENDICES

1 Copy of questionnaire sent out to 120 forest resource managers and researchers in the southern Interior, November 1987 51

2 List of Latin and common names of species referred to in the text 55

TABLES

3.1 Average ranking of preferred extension mechanisms 12

3.2 Average ranking of vegetation management research needs 13

3.3 Numbers of respondents identifying particular vegetation complexes as the highest priority for further research 14

3.4 Biogeoclimatic zones identified as having the greatest need for additional research 14

3.5 Average ranking of decision making tools by questionnaire respondents 15

4.1 Major complexes of competing vegetation in the southern Interior 17

5.1 A summary of southern Interior FRDA research projects listed by vegetation complex, biogeoclimatic zone, and area of activity 26

FIGURES

1.1 Spatial and temporal scales associated with various levels of forestry activity, from detailed process-based research, up to national forest policy development 3

1.2 Forestry can be viewed as a nested set of activity systems. 3

1.3 Research to understand the interactions between crop and non-crop vegetation is required at many different levels of biological organization. 4

3.1 Distribution of respondents by climatic region (dry, moist, wet, other) and by occupation 11

3.2 Responses to Question 3 (Is existing research information being fully utilized in operational vegetation management?), by occupation 12

SECTION 1

THE NEED FOR AN OVERALL VEGETATION MANAGEMENT STRATEGY

The organization of forest vegetation management research in the southern Interior is based on the results of a survey made in 1986 by the B.C. Ministry of Forests and Lands (D. Lloyd, pers. comm.) of what industry and Ministry foresters felt were the key problem plant complexes in each biogeoclimatic zone. The geographical and ecological stratification of the research aims to ensure that the available research effort is allocated to priority problems across the entire southern Interior.

This is a sound approach, and has produced a useful program of problem-specific and site- or plant complex-specific research projects. However, it has lacked an overall framework through which individual project results could be synthesized into more generalizable tools of assessment, prediction and management. There are simply too many site/plant complex/treatment option combinations for anyone to consider undertaking independent research projects on every combination within the period dictated by the needs of forest managers for answers. What is required is an integrating framework, in the form of a "research strategy," that can help us to synthesize the results of individual research projects into portable, generally applicable methods of assessment, prediction, and management. The genesis of this report was the recognition of the need for this integrating framework.

1.1 Origin and Scope of the Report

The origin of this report was a request from Mr. Alan Vyse, Regional Research Forester, and Mr. Denis Lloyd, Regional Forest Ecologist, B.C. Ministry of Forests, Kamloops Region, that a strategy statement be prepared, to guide the FRDA Technical Advisory Committee of the southern Interior in funding vegetation management research in the 1989-91 period. Subsequent discussions broadened the scope of the report to include the preparation of a research strategy that could become the basis for a long-term program of research on vegetation management in the southern Interior, starting with the final 2 years of the FRDA program, and extending at least to the end of the century.

We were asked to consider a broad range of issues in vegetation management, including site preparation and species selection, seedling physiology and planting quality, the assessment, prediction and management of negative interactions between crop and non-crop vegetation, the design of field research installations, and the communication and implementation of research results. In short, the strategy was to examine vegetation management research as a system of activities from problem identification (assessment) through to the implementation of research results as on-the-ground vegetation management treatments.

The broad scope of the report, together with the relatively short time available for its preparation, precluded a detailed study of any single topic. If the research strategy proposed in this report is accepted, many of the individual components of the strategy will require more detailed development.

1.2 Objectives of the Report

The following objectives guided the development of the report:

1. To identify the needs of forest managers in the southern Interior for methods and tools for the assessment, prediction and management of problems associated with non-crop vegetation.
2. To identify the knowledge and data required for the development of such methods and tools.
3. To review past and present vegetation management research in the southern Interior, and to compare the knowledge and data produced by that research to the knowledge and data required under (2) above.
4. On the basis of this comparison, to identify knowledge and data gaps, and the types of research that should be conducted to provide the missing knowledge and data.
5. To identify existing and developing technologies that are being used as an aid in vegetation management in agriculture, and in forestry outside of British Columbia, which could assist in the

assessment, prediction and amelioration of vegetation management problems in the southern Interior.

6. To identify the types of research needed to make these technologies available to resource managers in the southern Interior.
7. To identify important questions that need to be addressed about vegetation management, but which are not specifically components of vegetation management per se.
8. To identify mechanisms for "technology transfer": for making the results of vegetation management research available to field-level resource managers and management planners.
9. To summarize all of the above in a comprehensive "vegetation management research strategy" for the southern interior.

Because of time limitations, not all of these objectives were achieved as fully as had been hoped. Further work is undoubtedly needed on some of the above topics.

The following issues are not addressed in this report: future utilization of species which are presently undesirable (aspen, birch, cottonwood); the role of species selection, stock and seedling condition in vegetation management; and the contribution of regeneration strategy, particularly reliance on natural regeneration, to future vegetation management problems.

1.3 Conceptual Approach in Developing the Strategy

Several basic principles were established from which the research strategy was developed:

- That vegetation management research in British Columbia should be more than a problem-specific and site-specific exercise aimed only at increasing our understanding of vegetation management problems; it should also provide the knowledge necessary for the development of more generally applicable tools of vegetation management.

  It is assumed that these tools can be classified into three major categories: tools of assessment, tools of prediction, and tools of management.

- That research will be required at a variety of spatial and temporal scales, covering various levels of biological organization and various levels of forest management activity.

  Research is needed at the individual plant and soil/microclimatic process level, at the field research plot level, at the stand level, and at the regional (timber supply area) level (Figure 1.1). It is also needed at various levels within the overall stand-level crop production system (Figure 1.2). (See also arguments in Kimmins 1986 and Baskerville 1986.)

- That research will be needed both to increase our understanding of vegetation management problems, and to improve our ability to predict these problems.

  The type of research needed for improved understanding will often be different from the type of research needed for prediction (Figure 1.3).

- That vegetation management research should be considered in the context of rotation-length silvicultural systems, and not in terms of individual stages of the rotation. Vegetation management should certainly not be considered only within the 2- to 3-year lifespan of most research projects. This means that long-term field trials must be established and carefully monitored over time scales that are relevant to the overall objectives of management. Where this time scale is too long relative to the needs for improved vegetation management decision-making, alternative prediction tools should be developed that can address the time scales involved (Kimmins 1985; Herbicide Sub-Committee 1985).

- That because timber production is an economic activity, and because production of value is as important as the production of volume, rotation-length economic analyses should be a major component of a vegetation management research strategy.

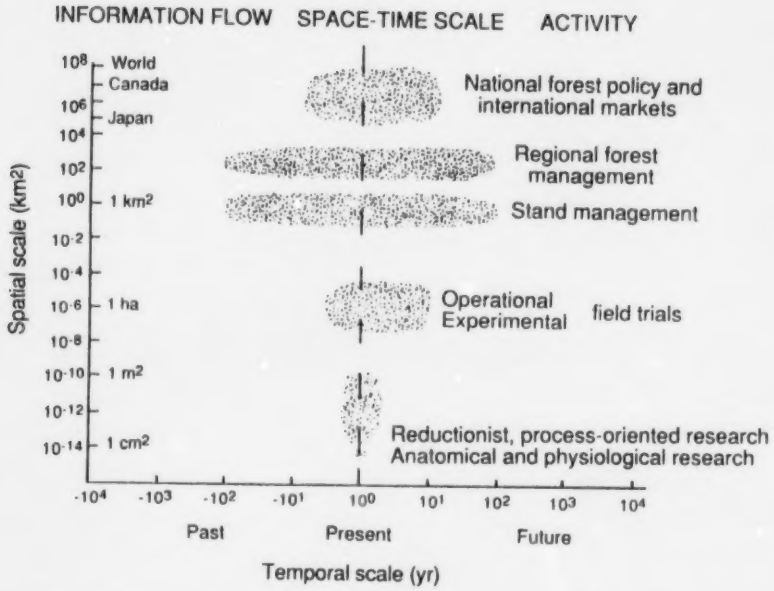

FIGURE 1.1. Spatial and temporal scales associated with various levels of forestry activity, from detailed process-based research, up to national forest policy development (Kimmins 1986).

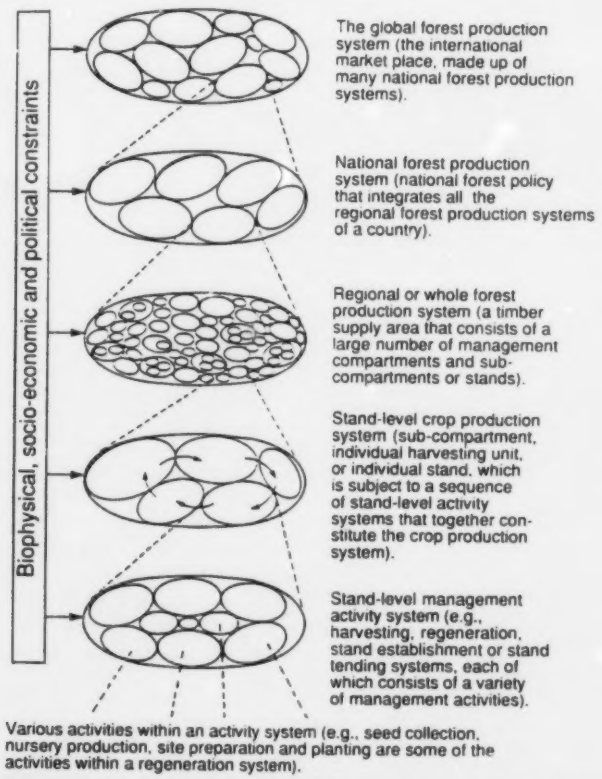
Biophysical, socio-economic and political constraints
The global forest production system (the international market place, made up of many national forest production systems).
National forest production system (national forest policy that integrates all the regional forest production systems of a country).
Regional or whole forest production system (a timber supply area that consists of a large number of management compartments and sub-compartments or stands).
Stand-level crop production system (sub-compartment, individual harvesting unit, or individual stand, which is subject to a sequence of stand-level activity systems that together constitute the crop production system).
Stand-level management activity system (e.g., harvesting, regeneration, stand establishment or stand tending systems, each of which consists of a variety of management activities).
Various activities within an activity system (e.g., seed collection, nursery production, site preparation and planting are some of the activities within a regeneration system).

FIGURE 1.2. Forestry can be viewed as a nested set of activity systems. Vegetation management and research related to forestry is needed at several different levels, and has implications at the other levels (Kimmins 1986).

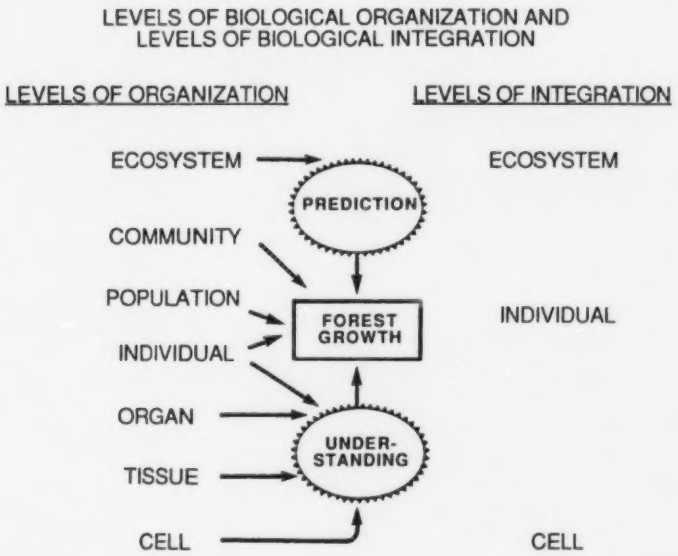

FIGURE 1.3. Research to understand the interactions between crop and non-crop vegetation is required at many different levels of biological organization. However, accurate prediction about future conditions or events must be based on the true level of biological integration above the level of interest (Kimmins 1985). This figure shows that understanding of past and present forest growth requires knowledge of processes at the cellular, tissue, organ, individual and population levels of organization; prediction of future growth requires an ecosystem-level understanding. Similarly, accurate prediction of the outcome of interspecific competition depends on our understanding of processes at the community level and at the ecosystem level.

This is particularly important because many vegetation management investments take place at or near the start of the rotation. Such economic analyses require an accurate prediction of future yields and their economic value and may require development of improved methods of yield prediction. Because of the complexity of the determination of future yields, such methods should be based on an understanding of ecosystem structure and function. The only available method of making ecosystem-level, rotation-length yield predictions is the use of ecosystem-level forest management simulation models (Kimmins 1988; Kimmins and Sollins 1989).

SECTION 2

PAST AND PRESENT OPINIONS CONCERNING VEGETATION MANAGEMENT PROBLEMS AND RESEARCH NEEDS

2.1 Reports on Vegetation Management in British Columbia

Prior to reports by Conard (1984) and Boateng (1984), little had been published on the role of non-crop vegetation and its management in British Columbia. Kimmins and Fraker (1973) and Kimmins (1975) provided literature reviews on the use of herbicides in forestry, and discussed some of their ecological effects, but lack of funding for research on herbicides and other aspects of vegetation management resulted in few publications and reports on the subject for the following decade. However, concern about the negative effects of non-crop vegetation on tree crop establishment and growth increased steadily over this period, and led to the commissioning of the Conard and the Boateng reports in the early 1980's.

2.1.1 The Conard report

Conard (1984) prepared a review of forest vegetation management problems in British Columbia. Her report discusses associated research needs, recommends personnel and the educational programs required to deal with these problems, and outlines a framework for establishing a research program. Conard identified 19 complexes of potential problem vegetation types in the province: 8 dominated by non-crop hardwood and coniferous tree species, 6 by shrub vegetation, and 5 by herbaceous species. Of these 19 types, 11 were noted as occurring in the southern Interior.

Conard also identified 10 areas of forest vegetation management research that should receive high priority:

1. Establishment of screening trials to evaluate the efficacy of vegetation management techniques.
2. Studies of the effects of site preparation and harvest methods on the establishment and growth of crop trees.
3. Investigations of the effects of the timing of weed removal on crop tree growth.
4. Influence of species composition of the non-commercial vegetation on crop tree establishment and growth.
5. Development of operational methods for assessing and predicting levels of competing vegetation.
6. Studies on the environmental fate of herbicides, and on environmental impacts of herbicides and alternative treatments.
7. Incorporation of an evaluation of the influence of non-crop vegetation into stock type trials.
8. Identification of environmental factors limiting crop tree growth in the major biogeoclimatic zones, and of the influence of non-crop vegetation on levels of these factors.
9. Studies of the autecology of major non-crop plant competitors.
10. Development of a system for classifying and predicting seral vegetation.

Conard reviewed the basics of vegetation management science, and the five major stages in stand development at which management practices can have a significant impact on non-crop vegetation: harvest, site preparation, stand establishment, early stand growth, and tending of well-established stands (e.g., plantation, cleaning and thinning). The report describes the major tools of vegetation management, notably: prompt reforestation with healthy and vigorous seedlings; the use of large seedlings; mechanical site preparation, with its attendant risk of soil damage and often short-term benefits; and use of herbicides. Major complexes of competing vegetation are reviewed, and the report stresses the need for a system of classifying seral vegetation as a basis for any analysis of

vegetation management research needs. The report briefly discusses each of the 10 recommended research priorities and concludes with a discussion of human resource needs, education, and training for vegetation management in the province.

The Conard report has been influential in drawing attention to the research and educational needs of the provincial vegetation management program, and it stimulated much discussion and several subsequent problem analyses. It did not, however, provide an actual strategy for research, it was not specific to the southern Interior, and it did not discuss how the results of the 10 proposed research priorities could be integrated into a series of management decision support tools.

2.1.2 The Boateng report

In a report produced concurrently with Conard's, Boateng (1984) presents a summary of the available information on the extent of vegetation management problems in British Columbia. The report estimated that in 1983 there were 2.9 million ha of good and medium land in the province on which some control of non-crop vegetation was needed. Such control, the report estimated, could result in increased annual fibre yields of about 8.4 million m^3. The report also estimated that the area of clearcuts being "lost" to non-commercial vegetation was about 49 000 ha/yr. Conard (1984) suggests that this is an underestimate, based on her experience in Oregon with clearcuts on which crop tree growth is inhibited by competing vegetation. Boateng suggests that successful vegetation management could increase stumpage payments in the province by $54 million (1982 dollars), and the value of timber shipments by $717 million (1983 dollars). Although these figures are based on several assumptions and are subject to considerable uncertainty, they do indicate the magnitude of the problem that non-crop vegetation may cause.

The Boateng report shows the condition of vegetation management at the time of writing. However, plant communities are dynamic, and the report does not deal with the question of how many of the unrestocked areas will restock naturally in time. This "snapshot" evaluation should be considered in the context of the natural processes of change (succession) in British Columbia's forests.

2.1.3 The Sutton review

Sutton (1985) reviewed vegetation management across Canada. He noted that, nationally, out of a total productive forest land base of 251 million ha, 30 million ha of forest land were thought to be inadequately regenerated or stocked. The report reviews various methods of forest weed control and discusses how the method of control might be chosen. Sutton notes that, unlike agricultural weed problems, forests are ecologically heterogeneous and, because of the long time scale and low intensity of management, unpredictable. This adds considerable risk to vegetation management in forestry, because of the lack of good information about the long-term efficacy and economics of vegetation management. For a given level of weed control, different weed control treatments have very different implications for the reinvasion of weeds, for soil moisture, temperature, aeration and fertility, for insects and diseases, for wildlife and water quality, etc. The report stresses that, although vegetation management is often thought of as a simple choice between alternative control techniques to gain short-term relief from non-crop vegetation, it should be approached from a systems point of view; and the implications on the whole ecosystem should be considered.

Neither the Sutton review nor the two herbicide-related reports described in section 2.1.6 are specific to the southern Interior. However, they do contain many important points that can usefully be applied there.

2.1.4 The Butt report

A review of regeneration problems in the Dry Southern Cordilleran Engelmann Spruce Subalpine Fir Subzone (ESSFa) was prepared by Butt (1987). In this study, historical records were examined, local silviculturists were interviewed, and other available information was collected.

Regeneration failure was not strongly associated with any particular site factor in the ESSFa. However, sites with rich trophotopes showed a small increase in regeneration failure, possibly as a result of greater amounts of non-crop vegetation. Competing vegetation appeared to be a serious regeneration concern in this subzone. Three main problem complexes were identified: pinegrass-

fireweed; false azalea-rhododendron; and Sitka alder.[1] Reliance on natural regeneration and the lack of adequate site preparation appeared to contribute to unsatisfactory restocking. Other causes of regeneration failure identified included: extensive use of bareroot Engelmann spruce and Douglas-fir stock; poor stock quality and condition; poor stock handling, planting and time of planting; and animal damage.

The report makes the following recommendations for further research:

- Identification of factors influencing the success of natural regeneration in the ESSFa and development of systematic techniques for selecting regeneration method.
- Improved understanding of plantation performance and identification of potential growth rates on a site-specific basis.
- Monitoring and identification of the effectiveness of different practices for regenerating ESSFa sites (e.g., natural regeneration, planting, stock types, planting season, species selection, site preparation, and vegetation management).
- Completion of a comprehensive field survey of regeneration of cutovers in the ESSFa to identify the nature and extent of regeneration problems and to develop more detailed recommendations.

2.1.5 The Butt-Bancroft report

A recent report on forest regeneration in the southern Interior is the study of silvicultural practices and forest regeneration in part of the Interior Cedar Hemlock zone by Butt and Bancroft (1988). In this study, historical records were reviewed and regeneration and site disturbance were examined on 131 sites in 109 clearcuts to seek correlations between regeneration performance (survival and growth of planted trees, and the extent, rate and growth of natural regeneration) and silvicultural practices. The authors reported that 25 000 of 75 000 ha of clearcuts from the 1965-1985 period are currently not satisfactorily restocked (NSR) in the Clearwater and Horsefly Forest Districts.

The sites with the greatest regeneration problems were characterized by north aspects, and subhygric and hygric hygrotopes. Some had sustained the least disturbance of any sites from logging and/or slashburning. Low soil temperature, competing vegetation, frost, and excess moisture appeared to be the ecological factors presenting the greatest difficulties for satisfactory regeneration. Silvicultural practices which have contributed to regeneration failures include inadequate site disturbance, delayed site preparation, delayed planting, and wrong choice of species. Poor stock quality, poor seedling handling and planting, and climatic stress on seedlings soon after planting were identified as factors which have contributed to poor regeneration performance. Fireweed was identified as the single most important competing weed species.

The report presented ten recommendations that identified the need for:

- Use of site disturbance in a manner that is consistent with the ecological tolerance of the site.
- A frost hazard classification, and the avoidance of Douglas-fir on frosty sites.
- Planting of large stock on fireweed-dominated or poor sites.
- More research to quantify hardwood tree - conifer crop interactions, and the avoidance of site damage through the excessive use of mechanical site treatment.
- More careful application of tree species selection.
- More "aggressive" screefing on sites that lack adequate disturbance.
- Ranking of backlog sites for treatment.
- Planting as the major required form of regeneration, with natural regeneration only being relied on for in-fill.

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[1] See Appendix 2 for Latin names and botanical authorites.

- More uniform stocking standards to ensure consistent reporting of NSR problems from different Forest Regions.

The Butt-Bancroft report indicates that regeneration failure in the southern Interior is a multiply-determined phenomenon, which requires an ecologically sensitive site- and problem-specific approach to solutions. Interference from non-crop vegetation is clearly a major reason for regeneration failure on some site types, but the report does not support the idea that a ubiquitous program of vegetation management would solve all of the problems. A multi-disciplinary approach is required, an important component of which would be vegetation management.

2.1.6 Reports relating to the herbicide option in vegetation management

Vanden Born and Malik (1984) and the Herbicide Sub-Committee (1985) reviewed the use of herbicides in forest vegetation management. Both reports noted that competition, and other forms of interference from non-crop vegetation, constitute one of the major silvicultural problems faced by forest managers. Both stress that the herbicide option may have significant advantages over alternatives in many situations; both note that the problems created by non-crop vegetation have been ignored or underrated in the past.

The Herbicide Sub-Committee (1985) report emphasizes the need for an integrated system of regeneration and tending rather than considering weed control in isolation. It also calls for improved education and training in vegetation management, for the development of systems to define, monitor and evaluate forest vegetation management problems and treatment alternatives (including economic evaluations), and for research to improve our knowledge of the ecology and physiology of competing vegetation, and our ability to classify and predict early secondary succession.

2.1.7 Research protocols

The need for a standardized methodology for vegetation management treatment screening trials led to the Herring and Pollack (1985) and Pollack and Herring (1985) reports. Standard protocols are essential for the consistent collection of field data and ensure that sound and defendable study designs are used. These protocols will effect a major improvement in the results from certain types of vegetation management research. There is, however, an urgent need for similar types of protocols to be developed for various other aspects of vegetation management research, and for the refinement and modification of these protocols using results of past trials.

2.1.8 Scoping sessions

As useful as the above reports are, they do not on their own provide an adequate basis for the design of an overall vegetation management research strategy for the southern interior of British Columbia. In 1986, a meeting was held to identify vegetation complexes of cold, hot-dry, and cool-wet areas for the research priorities of the southern Interior. Three workshops (in vegetation management, stock quality, and microclimatic monitoring) reviewed existing FRDA-supported and other research, attempted to establish research priorities, and tried to rank proposals for new research. The major conclusion of the Penticton meeting was that the ranking of research priorities cannot be done until an overall research strategy has been established and objectives of vegetation management research are clearly identified.

A subsequent meeting was held to establish a "research framework for cold sites" (the Engelmann Spruce - Subalpine Fir zone was selected as the focus). This meeting resulted in the development of an interaction matrix and the identification of the major linkages between the factors determining crop growth and ecological succession. As well, a broad conceptual model was developed.

2.2 Summary

Until 1984, there was very little written material available on forest vegetation management in Canada, less for British Columbia, and even less for the southern Interior. Although there is a rapidly increasing volume of technical reports and scientific papers on vegetation management, information in a form that is useful to forest managers is still lacking. Managers need to understand and be able to predict vegetation management problems, and they need methods by which to differentiate what is truly a

vegetation management problem from a failed regeneration strategy or silvicultural procedure, or from a physical or chemical environmental condition that is inimical to regeneration, with or without competing vegetation.

There is clearly a need to focus research into a series of decision support tools that will facilitate managers' understanding and assessment capabilities, and this will require a systems approach to vegetation management. An *ad hoc* program of scientific research will not, on its own, satisfy the need, irrespective of the technical and scientific merits of the individual research projects. Tools must be developed to help resource managers make economically and ecologically sound vegetation management decisions.

SECTION 3

A SURVEY OF CURRENT OPINIONS REGARDING VEGETATION MANAGEMENT AND RESEARCH NEEDS

A vegetation management opinion survey was conducted in the southern Interior in 1986 by Denis Lloyd, B.C. Ministry of Forests. Since vegetation management needs have been undergoing rapid change, a second survey was conducted during late 1987. A short questionnaire (Appendix 1) was distributed to 110 forest, range, and wildlife managers and forestry researchers working in, or doing work relevant to, the southern Interior. Eighty-eight questionnaires (80%) were completed and returned during November and December of 1987.

This section summarizes information obtained from this questionnaire.

3.1 Questionnaire Responses

Questions 1 and 2: In which climatic region of the southern Interior of British Columbia is most of your work conducted, and what is the focus of most of your work activities?

Forest managers represented 53% of the respondents, range managers 17%, wildlife managers 10%, and researchers 19%. Because of the small sample sizes for wildlife managers (9), range managers (15), and researchers (17), responses from these groups should be interpreted cautiously. The majority of the respondents worked in dry and/or moist climatic regions. Forest managers and researchers who responded indicated that they worked predominantly in the moist region; work by range and wildlife managers was focussed predominantly in the dry region (Figure 3.1).

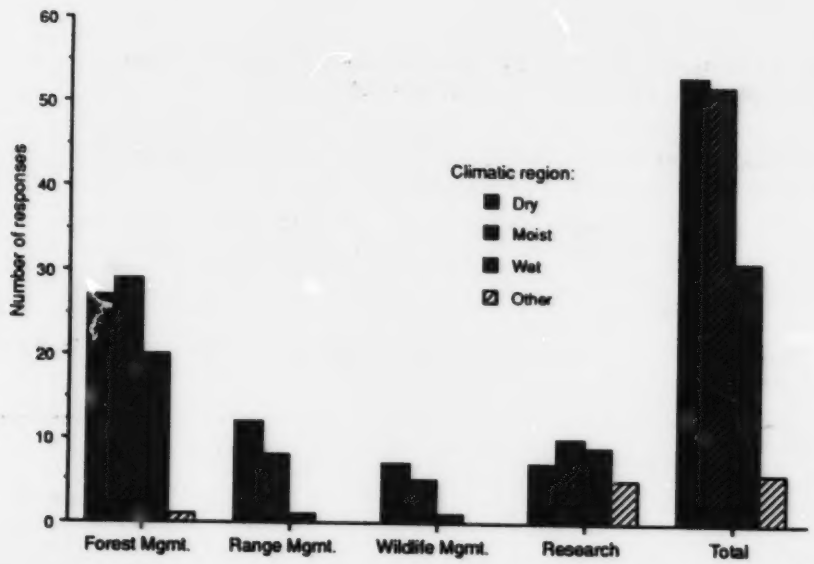

FIGURE 3.1. Distribution of respondents by climatic region (dry, moist, wet, other) and by occupation (Questions 1 and 2).

Question 3: Do you feel that existing research information is being fully utilized in operational vegetation management?

The majority of respondents (88%) did not feel that existing research information was being fully used in operational vegetation management (Figure 3.2). Comments indicated that this lack of implementation was the result of operational staff not having adequate time to review published research reports, or adequate technology transfer mechanisms. This response may reflect a perception that although a lot of research is being conducted in the southern Interior, the products of this research have not yet been made easily available to operational staff. In reality, much of this research was only initiated recently, and therefore the results are only now becoming available. However, responses clearly indicate that improved communication between researchers and operational staff is needed.

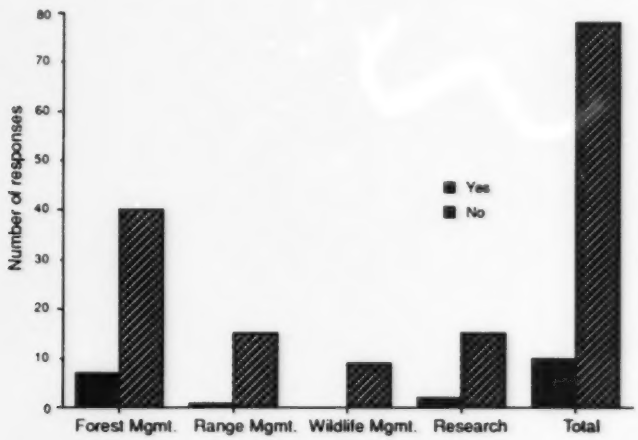

FIGURE 3.2. Responses to Question 3 (Is existing research information being fully utilized in operational vegetation management?), by occupation

Question 4: Which of the following would you find most useful for learning about new research findings or new techniques in vegetation management?

Respondents in all fields of work indicated a preference for field trips and demonstrations as a method for learning about research results (Table 3.1). Courses, training sessions and workshops were ranked

TABLE 3.1. Average ranking of preferred extension mechanisms (Question 4). Ranks range from 1 (most useful) to 6 (least useful).

	Occupation				
Extension mechanism	**Forestry**	**Range**	**Wildlife**	**Research**	**Total**
A. Conferences	4.44	3.07	3.12	4.00	4.12
B. Courses and Workshops	2.20	2.47	3.62	3.06	2.56
C. Reports	4.33	4.80	3.00	3.50	4.13
D. Field guides	3.09	3.53	3.38	3.81	3.34
E. Field trips	2.07	2.33	2.50	2.69	2.28
F. Discussions	4.70	4.00	5.38	3.73	4.46

second by all except wildlife managers, who identified research reports and technical conferences as being more useful than courses. The overall ranking of communication mechanisms was:

1. field trips and demonstrations
2. courses, training sessions, or workshops
3. printed field guides or handbooks
4. technical conferences
5. printed research reports
6. informal discussions

Question 5: What are the priority needs in vegetation management research?

Perceptions of vegetation management research needs reflected the interests of the respondent groups. Forest managers and researchers and range managers indicated that research aimed at developing operational tools for assessing competition and interference was the highest priority. Wildlife managers indicated that this had the lowest priority of the five areas (Table 3.2). Second and third rank were given to research on the prediction of vegetation development and brush hazard and studies of the effectiveness of vegetation management techniques (screening trials). Wildlife managers selected as first and second priorities, studies of environmental impacts and studies dealing with the prediction of succession.

TABLE 3.2. Average ranking of vegetation management research needs (Question 5). Ranks range from 1 (most useful) to 6 (least useful).

	Occupation				
Category	**Forestry**	**Range**	**Wildlife**	**Research**	**Total**
A. Screening trials	2.83	3.00	3.44	2.87	2.93
B. Environmental impacts	3.96	2.79	2.33	2.60	2.53
C. Competition assessment	2.21	2.47	4.00	1.87	2.38
D. Hazard prediction	2.47	2.73	2.44	2.69	2.55
E. Economics	3.53	3.86	2.78	3.75	3.55

Question 6: For which vegetation complex is there the greatest need for further research?

Respondents from forest management and research indicated that greatest research needs were in the mixed shrub-herb complex (Table 3.3). Forest managers ranked the aspen-mixed hardwood complexes as second, the alder-pinegrass complex as third, and the pinegrass complex as fourth. Range managers indicated that greatest research needs were in the pinegrass complex and wildlife managers assigned highest priority to the alder-pinegrass complex.

Question 7: In which biogeoclimatic zone is there the greatest need for further research on forest regeneration?

The ESSF and Interior Cedar Hemlock (ICH) zones were identified as the biogeoclimatic zones in the southern Interior with the greatest need for forest regeneration research (Table 3.4). Range managers assigned priority to the Interior Douglas-fir (IDF); wildlife managers ranked this zone as second; forest managers and researchers ranked it third and fourth, respectively. No respondents selected the Ponderosa Pine Bunch Grass zone (PPBG). Responses to this question reflect both the areal extent of these zones and the extent of problems encountered with forest regeneration in each of these zones.

TABLE 3.3. Numbers of respondents identifying particular vegetation complexes as the highest priority for further research (Question 6). (Numbers indicate number of respondents identifying a complex as the highest priority).

	Occupation				
Complex	**Forestry**	**Range**	**Wildlife**	**Research**	**Total**
Pinegrass	6	4	0	1	11
Alder-pinegrass	7	2	0	0	9
Aspen and mixed hardwood	11	0	3	1	15
Mixed shrub	18	2	2	10	32
Ericaceous	4	0	1	0	5
Subalpine herb	0	1	0	1	2
Floodplain	0	0	0	1	1
Domestic	0	3	0	0	3
Other	0	1	2	1	4
Total	**46**	**13**	**8**	**15**	**82**

TABLE 3.4. Biogeoclimatic zones identified as having the greatest need for additional research (Question 7). (Numbers indicate number of respondents identifying a complex as the highest priority).

	Occupation				
Zone	**Forestry**	**Range**	**Wildlife**	**Research**	**Total**
PPBG	0	0	0	0	0
IDF	12	4	3	0	19
ICH	14	2	1	11	28
MS	1	2	0	1	4
SBS	3	2	0	1	4
ESSF	17	3	5	3	20
Total	**47**	**13**	**9**	**16**	**85**

Biogeoclimatic Aones: PPBG – Ponderosa Pine - Bunch Grass; IDF Interior Douglas-fir; ICH – Interior Cedar Hemlock; MS – Montane Spruce; SBS – Sub-boreal Spruce; ESSF – Engelmann Spruce - Subalpine Fir.

Question 8: Which type of tool would be most useful for predicting and assessing vegetation management problems?

Amongst the four decision support tools or methods included in the list, field guides and handbooks were strongly preferred by forest managers, wildlife managers and researchers (Table 3.5). Technical experts were rated as a second choice by forest managers and researchers; as first choice by range managers; and as third choice by wildlife managers. Wildlife managers indicated a preference for simulation models over technical experts and computer expert systems. However, comments accompanying responses to this question indicated that many people were unfamiliar with computer models and expert systems. Consequently many of the responses to these latter two types of tool may not represent an informed opinion. In contrast to foresters, wildlife managers have used simulation models for over a decade, and this familiarity is reflected in the relatively higher preference that they show for computer models compared to the other groups of respondents.

TABLE 3.5 Average ranking of decision-making tools by questionnaire respondents (Question 8). Ranks range from 1 (most useful) to 6 (least useful).

Tool	Occupation				
	Forestry	Range	Wildlife	Research	Total
A. Experts	2.30	1.62	2.60	2.31	2.21
B. Field guides	1.67	2.08	1.80	1.56	1.73
C. Models	3.41	3.11	2.40	3.60	3.35
D. "Expert systems"	2.91	3.44	2.75	2.62	2.91
E. Other	3.73	3.00	2.00	3.33	3.30

3.2 Summary

As one might have predicted, opinions about vegetation management vary between managers of different resources, and between managers of any particular resource in different areas. However, results of our survey also indicate that the feeling amongst forest managers is that:

- research results have not yet been adequately communicated;
- field trips, demonstrations, and workshops/training courses are preferred over research reports;
- research should focus on developing operational decision support tools in vegetation assessment and prediction, and in the prediction of the efficacy and effects of vegetation management techniques;
- the greatest research needs are in the mixed herb-shrub complex, the aspen-mixed hardwood complex, the alder-pinegrass complex, and the pinegrass complex (in that order);
- the ESSF and ICH zones are most in need of vegetation management research; and
- field guides and handbooks are currently the preferred type of decision support tool.

SECTION 4

EARLY SERAL VEGETATION IN THE SOUTHERN INTERIOR AND THE NATURE OF INTERACTIONS BETWEEN CROP AND NON-CROP VEGETATION

Forests occur in a broad range of environments in the southern interior of British Columbia. Climatic conditions in this area range from warm, dry, low-elevation areas supporting savanna forests, to cold, moist, high-elevation areas supporting Engelmann Spruce - Subalpine Fir forests. Within any single climatic regime there is also a broad range of site conditions associated with variations in topographic and edaphic factors. This range in environmental conditions and the associated floristic diversity leads to substantial variety in the characteristics of the early seral plant communities which develop following forest harvesting.

Early seral vegetation which may compete with conifers in the southern Interior can be classified into 14 complexes. The species associated with each of these complexes are described in Table 4.1.

TABLE 4.1. Major complexes of competing vegetation in the southern Interior (modified from Conard 1983). (Zones indicated in "()" are those in which the complex has a limited occurrence.)

Complex	Major species	Biogeoclimatic zone	Sites
Pinegrass	*Calamagrostis rubescens*	IDF, ICH, MS, PPBG, SBS, ESSF	Dry to Fresh
Fireweed	*Epilobium angustifolium*	(IDF), ICH, MS, ESSF	Dry to Wet
Fern	*Athyrium filix-femina* *Dryopteris assimilis* *Pteridium aquilinum*	ICH	Fresh to Wet
Dry Alder	*Alnus viridis* ssp. *sinuata* *Epilobium angustifolium* *Calamagrostis rubescens*	ICH, MS, SBS	Dry to Fresh
Wet Alder	*Alnus viridis* ssp. *sinuata* *Alnus incana* ssp. *tenuifolia* *Rubus parviflorus* *Lonicera involucrata* *Calamagrostis canadensis* *Athyrium filix-femina* *Dryopteris assimilis*	ICH, (MS), ESSF	Wet
Mixed Shrub	*Rubus parviflorus* *Rubus idaeus* *Lonicera involucrata* *Acer glabrum* *Alnus viridis* ssp. *sinuata* *Paxistima myrsinites* *Sambucus racemosa* *Oplopanax horridus* *Menziesia ferruginea* *Salix* spp. *Cornus sericea* *Athyrium filix-femina* *Pteridium aquilinum*	ICH, ESSF	Fresh to Wet
Dry Shrub	*Ceanothus velutinus* *Paxistima myrsinites* *Shepherdia canadensis* *Symphoricarpos albus* *Holodiscus discolor* *Physocarpus malvaceus*	ICH, IDF	Dry to Fresh

TABLE 4.1. Continued

Complex	Major species	Biogeoclimatic zone	Sites
Ericaceous Shrub	*Rhododendron albiflorum* *Menziesia ferruginea* *Vaccinium membranaceum*	ESSF	Dry to Moist
Subalpine Herbs	*Valeriana sitchensis* *Luzula* sp. *(Epilobium angustifolium)*	ESSF	Fresh to Wet
Aspen	*Populus tremuloides*	IDF, ICH, MS	Various
Cottonwood - Shrub	*Populus balsamifera* *Lonicera involucrata* *Cornus sericea* *Sambucus racemosa* *Rubus parviflorus* *Alnus viridis* ssp *sinuata* *Alnus incana* ssp. *tenuifolia* *Calamagrostis canadensis*	IDF, ICH	Floodplains
Mixed Hardwood - Shrub	*Populus tremuloides* *Populus balsamifera* *Betula papyrifera* *Salix* spp. *Alnus incana* ssp. *tenuifolia* *Alnus viridis* ssp. *sinuata*	IDF, ICH, MS	Various
Willow	*Salix* spp.	IDF, ICH, MS, ESSF	Moist to Wet
Introduced Grasses	Domestic grasses	(PPBG), IDF, (ICH), MS, (ESSF)	Various

In addition to the spatial variability of the vegetation, there are diverse patterns of secondary succession in British Columbia. This diversity results from interactions between climate, soils, the nature and severity of the disturbance from which these communities originated, and biotic factors. The biogeoclimatic-ecosystem classification of British Columbia provides a useful framework for describing the spatial variability of the vegetation in terms of major ecological site characteristics, the climax vegetation, and the inherent productivity of forest lands. However, patterns of early secondary succession cannot be predicted easily from the site classification alone. Plant population and community dynamics interact with ecological site characteristics to influence community characteristics and patterns during secondary succession. This section briefly reviews the factors which influence the development and dynamics of non-crop plant communities and the nature of interactions between early seral vegetation and crop species.

4.1 Factors Influencing the Pattern and Rate of Secondary Succession

The composition of early seral plant communities is influenced by the survival of species that were present before disturbance ("bud banks"), by seed stored within the ecosystem ("seed banks"), by seed arriving from adjacent areas ("seed rain"), and by the germination, survival, and growth of each species under the existing environmental conditions and competition regimes.

Harvesting operations that cause little damage to aboveground parts of understory vegetation, such as winter logging on snow, may result in communities dominated by the species which were present in the understory before harvesting (e.g., white-flowered rhododendron and false azalea in interior high-elevation forests). Similarly, activities that remove aboveground parts but cause minimal damage to buds, roots, or rhizomes (e.g., slashburning) may result in the regrowth (from bud banks) of many of the existing shrubs and herbs (e.g., thimbleberry, fireweed, and bracken). Some plants, such as aspen, may resprout in abundance from extensive root systems after stems have been cut.

Seed banks (viable seeds accumulated either in the forest floor or the upper mineral soil, or stored in unopened reproductive structures in the vegetation canopy) may contribute to the establishment of shrubs, herbs, or trees following disturbance. Several shrub species may germinate from seed stored on site, including small seeded species such as thimbleberry and red raspberry, and larger seeded species such as Douglas maple. Seed of some species may remain viable in forest floor horizons for long periods of time after all live plants of the species have disappeared from the ecosystem. In Idaho and parts of southern British Columbia, for example, dense snowbrush communities may develop following broadcast burning even though there was no visible evidence of snowbrush plants in the mature stand (Gratkowski 1962).

The movement of seed onto a site (seed rain) following disturbance is often important in determining the development of seral communities. Several million seed may arrive annually in 1 ha of disturbed land (Archibold 1980). This seed rain is likely to make the largest contribution to community characteristics on sites where seed banks and bud banks have been destroyed. Fireweed produces abundant quantities of seed which can be carried by wind for several hundred metres over adjoining areas. Seeds from thimbleberry, raspberry, elderberry, and blueberries may be transported by animals and deposited in their excrement. Germination of some of these seeds may be aided by the action of the digestive enzymes of the animals. Within a particular climatic area, the establishment and growth of plants from seed will depend on the seedbed conditions, weather conditions, and the presence of other plants which may interfere with their germination, establishment, and growth.

Under favourable conditions, plant communities may develop rapidly following harvesting. In the Sub-Boreal Spruce biogeoclimatic zone, both the rate of site invasion and the total vegetation cover after logging and burning increase with increasing soil moisture regime (Eis 1980; Hamilton and Yearsley 1988). Shrub and herb cover totalled 100% within 3 years after logging on moist to very moist (hygric) "alluvial" sites; on slightly dry to fresh (mesic) "Cornus-Moss" sites, total vegetation cover was only 46% six years after logging and burning. In temperate forested areas of the northeastern United States, shrub cover may achieve a leaf area index[2] equivalent to that of the mature deciduous forest within 3 years after harvest (Marks 1974).

The rate at which secondary succession proceeds is highly variable and will depend on environmental conditions; the rate at which changes in environmental conditions occur during succession; the population dynamics, longevity, tolerances, and growth rates of the species involved; and the interactions which occur between species. This variability contributes to the high variability in responses of vegetation to harvesting, to site preparation, and to vegetation management treatments.

4.2 Predicting Secondary Succession

A knowledge of, and ability to predict, successional patterns following harvesting, site preparation, and vegetation management activities is necessary to the development of ecologically and economically sound vegetation management strategies and treatments. The use of appropriate harvesting and site preparation techniques may, in many cases, eliminate the need for vegetation control later in stand development.

Predicting the effects of harvesting and site preparation on successional communities can be based on empirical data that describe how these activities influence the establishment and growth of plants under local environmental conditions. However, this requires data from large numbers of sites which have been monitored over a long period of time. Moeur (1985) describes the application of data from 10 000 vegetation plots located in five habitat types in Idaho, Montana, and Washington in the COVER module of the STAND PROGNOSIS model (Wykoff *et al.* 1982). The development of empirical models such as these requires a substantial investment in sample plot establishment and remeasurement. Such data are not currently available in British Columbia, and it is estimated that a decade of field work and an investment of over $1 million would be required to implement this approach for the important site types in the southern Interior.

Alternatively, predictions can be based on an understanding of species autecology and of the processes that determine plant population and community dynamics. Understanding how particular treatments influence the establishment and growth of plant populations gives foresters maximum flexibility

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[2] Leaf area index = the total amount of leaf surface area per unit of ground area; m^2m^{-2}

in making predictions about future community development. Computer simulation models could provide a useful synthesis of such information and would permit evaluation of the potential effects of a variety of treatments. However, our understanding of the dynamics of early seral communities in the southern Interior is limited and the data requirements for developing such process-based simulation models could be substantial.

An alternative to empirical or process modelling (the hybrid simulation approach) combines these two approaches. It also reduces data requirements while still retaining flexibility (e.g., Pastor and Post 1985, 1988; Shugart 1984; Kimmins 1988; Kimmins and Sollins 1989). The current status of knowledge about succession in southern interior forests suggests the development of the latter type of model, one that can utilize our current understanding of key processes in combination with empirical data on community development.

4.3 Interactions Between Crop and Non-crop Vegetation

Vegetation cover may benefit or interfere with the establishment and growth of crop tree species. Beneficial effects include the provision of thermal cover, the protection of soils from erosion, the provision of alternate hosts for mycorrhizae, and the retention and accumulation of nutrients. Detrimental effects include competition for resources (light, water, and nutrients) and physical, chemical, and environmental interference.

4.3.1 Beneficial aspects of vegetation cover

Light to moderate vegetation cover may provide thermal shelter to seedlings growing on warm, exposed sites. Vegetation cover, litterfall, and root systems may protect soils from erosion and may serve in the retention and accumulation of nutrient capital. The presence of alternate host species may help to sustain populations of desirable mycorrhizae.

Species capable of symbiotic nitrogen fixation (e.g., Sitka alder, mountain alder, soopolallie, snowbrush ceanothus, lupines) may improve or sustain site productivity through their contribution to site nitrogen capital. In western North America, rates of nitrogen fixation by Sitka alder range from 20 to 60 $kg.ha^{-1}.yr^{-1}$ (Binkley 1980, 1982). These rates should be sufficient to supply much of the growth requirements of a forest stand over a rotation (Miller and Murray 1979). Currently, however, no data are available on rates of nitrogen fixation in ecosystems of the southern Interior, and on the contribution of nitrogen fixation to site productivity.

4.3.2 Interference

Interference describes the negative effects of plants on each other. These negative effects can be due to physical damage, the release of phytotoxic chemicals, effects on microclimatic conditions, and competition for resources.

Physical Interference

Physical interference describes situations where vegetation physically damages crop species or physically hinders establishment and growth. This may include snowpress, smothering, and physical damage by species such as fireweed, ferns (bracken fern and lady fern), thimbleberry, and Sitka alder.

Snowpress and smothering by fireweed appears to be most common on cool, moist sites which have been burned. On these sites, fireweed may achieve high densities, high cover, and heights exceeding 1 m. Sitka alder may cause physical damage to seedlings in areas with moderate to high snowfall and where alder forms moderately dense canopies. Such problems appear to be most common in the ICH-ESSF and MS-ESSF transition zones.

Chemical Interference

Chemicals contained in litterfall or exuded from leaf, twig, and root surfaces of some plants can interfere with germination or growth of other plants. The effects on seed germination of litter and leachate from several species common in early seral plant communities in British Columbia were investigated by Del Moral and Cates (1971). Their results indicate that species such as elderberry,

waxberry, and white-flowered rhododendron can, under laboratory conditions, inhibit germination of Douglas-fir seed.

Allelopathic interactions may also involve inhibition of mycorrhizae and root growth. Plant chemicals may also indirectly affect soil microfauna and microflora, as well as soil pH. These indirect effects may have impacts on subsequent nutrient availability and uptake.

Microclimatic Interference

Vegetation cover may adversely affect air and soil temperatures. Moderate cover of grasses may, under some circumstances, create a greenhouse effect and lead to increased air temperatures near the ground. In turn, higher air temperatures may increase moisture stress or damage seedlings directly. Vegetation cover and organic soil surface layers can also reduce rates of heat exchange between overlying air and mineral soil, leading to increased incidence of summer frost damage (T.A. Black, Univ. of British Columbia, Faculty of Agriculture, pers. comm. 1987).

Vegetation cover may also cause reduced air and soil temperatures in early spring. In some cases, this may reduce the effective growing season available to seedlings and their physiological activity. Reductions in soil temperature may also lead to reduced activity of soil microbes and to reduced availability of macro-nutrients.

Competitive Interference

Competition is the adverse effect of one plant on another when both are using the same resource. Where competition for resources is a problem, vegetation management activities generally attempt to increase the proportion of site resources (light, water, or nutrients) allocated to crop species.

Light regimes under well-developed vegetation canopies may be very low. Less than 1% of full sunlight (PAR) may penetrate a well-developed thimbleberry canopy during mid-summer and, in dense patches of fireweed, light levels below 5% of full sunlight may be encountered.[3]

At low light levels, seedlings may be unable to fix sufficient carbon through photosynthesis to maintain existing tissues or to allow growth. Low light levels may also result in excessive stem elongation of seedlings of species such as Douglas-fir. The resulting long and weak stems may then be more susceptible to physical damage from fireweed or other vegetation, or to snow and wind damage.

The portion of the growing season during which the brush canopy has leaves may also be important in determining the degree to which competition affects conifer growth. Photosynthesis of evergreen conifers may occur during favourable snow-free periods in spring and fall when competing vegetation is leafless. Local climatic conditions will therefore influence the degree to which vegetation cover and light competition influence the growth of evergreen conifer seedlings.

The capture and use of soil resources by non-crop vegetation and the impact of this vegetation on crop establishment and growth depend on the availability of the resources and on the proportion of available resources, captured by the non-crop vegetation. Competition for soil resources may lead to reduced tree growth due to reduced leaf area, reduced photosynthetic efficiency of the foliage, and increased production allocated to root systems.

Vegetation overtopping crop tree seedlings, such as thimbleberry, and vegetation growing in the understory of established stands (e.g., snowbrush ceanothus, pinegrass) may compete for water and nutrients. Because the major pathway for water consumption is via leaf transpiration, water use is closely related to the leaf area of the species present, water-use characteristics of the species, and prevailing climatic conditions. Nutrient requirements are also closely related to leaf area since the greatest concentrations of nutrients are in foliage and since plant production is closely related to leaf area. The effect of competition for these resources depends on the site factors controlling resource availability, and on the proportion of these resources which are available for crop species.

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[3] Comeau, P.G. 1989. Unpublished data.

4.3.3 Other causes of regeneration failure

Poor seed supply, seed predation, adverse climatic conditions at time of germination, and unsuitable seedbed conditions for germination can also result in poor natural regeneration. Poor survival and establishment of planted seedlings can be the result of use of the wrong species, provenance or stock type; poor stock quality; and frost damage and other climatic influences. Careful monitoring of sites may be necessary to identify the cause of regeneration failure. Techniques for assessing the origin of regeneration failures are required so that appropriate remedies can be applied.

4.3.4 Indices of competition and interference

Leaf area of non-crop vegetation is a potentially useful parameter for assessing the intensity of competition between crop and non-crop vegetation, since canopy leaf area influences the availability of light to overtopped seedlings and is correlated with the availability and use of soil resources. Vegetation % cover is correlated with the leaf area of individual species (Wagner and Radosevich 1987; Comeau[4]) and is much easier to measure or estimate than leaf area. Proximity of competing plants to crop trees and the relative height of competing vegetation are also important to the intensity of competition (Brand 1986). Brand (1986) and Wagner and Radosevich (1987) demonstrate that % cover, relative height, and proximity of competing vegetation can provide reasonable predictions of the growth of Douglas-fir seedlings under conditions of varying competition from brush species. Wagner and Radosevich (1987) report that % cover of vegetation equal to or taller than 66% of tree height was the single best parameter for predicting stem diameter and stem volume of Douglas-fir on one site.

To be applicable on a range of sites, competition indices must consider the effects of resource availability as well as species abundance, size, and proximity of competing vegetation. The Biogeoclimatic Ecosystem Classification provides an effective method for characterizing prevailing environmental conditions and resource availability. It should be used together with other environmental parameters as a basis for the development and application of competition indices.

4.4 Summary

Forest sites in the southern Interior represent a broad range of environmental conditions ranging from dry savannah to cold, moist high elevation climates, and from rapidly to imperfectly drained soils. The major types of early seral plant communities which may compete with conifers are classified into 14 complexes.

The composition of early seral plant communities developing following disturbance is influenced by the survival of species that were present prior to disturbance, by seed stored within the ecosystem, by seed arriving from adjacent areas, and by the germination, survival, and growth of each species under the existing environmental conditions and competition regimes. The characteristics and longevity of early seral communities are controlled by interactions between the nature, intensity and time of disturbance, environmental conditions, plant population biology, and community ecology.

The plant communities which develop on a site following disturbance may be both beneficial and detrimental to the establishment, survival, and growth of conifer seedlings. Vegetation cover may help in the retention of nutrients on site. Through symbiotic nitrogen fixation, some species may contribute to site nutrient capital. Vegetation may interfere with crop plants through competition for resources (light, water, and nutrients), or through physical, chemical or mechanical interference. The nature of the interactions between crop and non-crop species is influenced by environmental conditions as well as by the abundance, size, and proximity of competing vegetation.

Models of competition and succession would provide useful tools for the assessment and prediction of the effects of vegetation cover on crop seedling growth and survival. Predicting competition problems requires the development of models that deal with both succession and interspecific competition. The current state of knowledge about succession and competition in southern Interior forests suggests that model development should initially focus on the creation of hybrid simulation models which use our current understanding of the key process, in combination with empirical data on community development.

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[4] Comeau, P.G. 1989. Unpublished data.

Environmental conditions strongly influence species composition, rates of community development, and the nature and intensity of interactions between crop and non-crop species. Therefore, development of tools of assessment and prediction should be linked closely with the Biogeoclimatic Ecosystem Classification which is being applied in much of British Columbia. The linking of such models with the ecological site classification will facilitate efficient development of the models and of site-specific interpretations which can be applied operationally.

SECTION 5

CURRENT STATUS OF VEGETATION MANAGEMENT RESEARCH AND INFORMATION IN THE SOUTHERN INTERIOR

Funding from federal and provincial governments under the Forest Resource Development Agreement (FRDA) is currently supporting more than 40 research projects in the southern Interior of British Columbia. In addition, related research is being conducted with support from other sources including the Canadian Forestry Service, the B.C. Ministry of Forests, universities, forest companies, and consultants.[5] Several research projects are also being conducted in other parts of the province and elsewhere in Canada and western North America, which can contribute to our understanding of vegetation management problems in the southern Interior and to the development of vegetation management tools.

This section reviews the major research directions currently being pursued, and of relevance to the southern Interior. Key areas requiring further research are identified. Similar reviews have been prepared for the province of British Columbia by the Herbicide Sub-Committee (1985) and Conard (1984).

5.1 Current FRDA Vegetation Management Research Activities in the Southern Interior

Table 5.1 outlines FRDA projects being conducted in the southern Interior up to December 1987. At this time projects had been completed or were underway in 9 of the 14 vegetation complexes identified in Section 3. Research projects are being conducted in all biogeoclimatic zones except the Ponderosa Pine Bunchgrass Zone (because of the lack of a major timber resource and a vegetation management problem in this zone).

The major areas being investigated in each project are identified in Table 5.1. Each one is related to the development of tools for: assessing vegetation management problems; predicting vegetation management problems and community responses to treatment; developing and appraising techniques for operational vegetation management; evaluating the economic and environmental impacts of vegetation management activities; and developing decision support tools to assist with the implementation of research findings by operational forestry staff.

5.1.1 Assessment

Competition and interference studies are currently under way for at least some plant complexes in all zones except the PPBG. Projects are being conducted in the pinegrass, fireweed, dry alder, mixed shrub, ericaceous shrub, and subalpine herb complexes. All of these projects should contribute to an improved understanding of the general nature of interactions between crop seedlings and non-crop vegetation. Some of these projects are acquiring empirical data on seedling growth relative to vegetation cover, proximity and height. These studies will provide useful information of relevance to the sites from which the data were acquired, but they may be limited in their general application. Some of the other projects are examining resource availability and competition for resources by non-crop vegetation.

Studies of competition and interference have been, or are being, conducted elsewhere in British Columbia and western North America (see Hamilton and Watts 1988). Brand (1986) reports on the development of a competition index for assessing the effects of competing brush on Douglas-fir growth. Wagner and Radosevich (1987) present the results of a competition study also aimed at the development of competition indices. Information from similar projects currently under way elsewhere in British Columbia should also provide information for some complexes which are not presently being studied in the southern Interior.

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[5] No attempt is made in this report to provide a complete historical record of past vegetation management research in the southern Interior.

TABLE 5.1. A summary of southern Interior FRDA research projects listed by vegetation complex, biogeoclimatic zone, and area of activity

Complex	Zone	Research area			
		Assessment	Prediction	Management	Impacts
Pinegrass	IDF	(3.1, 3.2)	–	(3.1)	(3.50)
	ICH	–	–	–	–
	MS	(3.2)	–	–	(3.50)
	ESSF	(3.2)	–	–	(3.50)
Fireweed	ICH	(3.21, 3.48)	(3.21[a])	(3.21, 3.46, 3.62)	(3.45)
	MS	–	–	–	–
	ESSF	(3.63)	–	(3.41)	–
Fern	ICH	–	–	(3.62)	–
Dry Alder	ICH	–	–	–	–
	MS	(3.49)	–	–	–
Wet Alder	ICH	–	–	–	–
	ESSF	–	–	(3.41)	–
Dry Shrub	IDF	–	–	–	–
	ICH	–	–	–	–
Mixed Shrub	ICH	(3.21, 3.25, 3.48)	(3.21[a] 3.44[a])	(3.21, 3.26, 3.29, 3.62)	(3.45)
	ESSF	–	–	–	–
Ericaceous Shrub	ESSF	(3.31, 3.32, 3.34, 3.40, 3.41)	(3.32[b], 3.39[c])	(1.17, 3.27, 3.31 3.35, 3.39, 3.40, 3.41)	–
Subalpine Herb	ESSF	(3.32, 3.34, 3.39, 3.41)	(3.32[b], 3.39[c])	(3.35, 3.39, 3.41)	–
Aspen	IDF	–	–	–	–
	ICH	–	–	–	–
	MS	–	–	(3.60)	–
Cottonwood - Shrub	IDF	–	–	–	–
	ICH	–	–	–	–
Mixed Hardwood- Shrub	IDF	–	–	–	–
	ICH	–	(3.44[a])	(3.21, 3.59)	(3.21, 3.29, 3.45)
	MS	–	–	–	–
Willow	IDF	–	–	–	–
	ICH	–	–	–	–
	MS	–	–	–	–
	ESSF	–	–	–	–
Introduced Grasses	IDF	–	–	–	–
	MS	–	–	–	–

a Studies of vegetation development following treatment.
b Studies of plant population biology preharvest and post-treatment.
c Retrospective studies associated with problem analyses.

5.1.2 Prediction

Prediction of vegetation development, competition problems, ecosystem responses to treatment, and long-term consequences of vegetation management have received limited attention in British Columbia. Changes in plant communities following brush control treatment are being monitored in connection with vegetation management studies now under way in the southern Interior. These projects are concentrated in fireweed, mixed shrub, ericaceous shrub, and subalpine herb complexes. A few studies have evaluated correlations between physical site characteristics (site classification), harvesting and site preparation activities, and subsequent vegetation management problems (ESSF

and ICH problem analyses). These retrospective studies will be useful for identifying priority areas and sites for future research. One study of vegetation development following harvesting and site preparation has been initiated in the southern Interior ICH and ESSF by Dr. Ed Oswald of the Canadian Forestry Service.

Empirical-mathematical and biological-process models are required to predict the characteristics of plant communities following harvesting, site preparation, brush control, and other silvicultural activities. Models for predicting community succession and competition with crop seedlings are also needed for forest ecosystems of the southern Interior. The COVER model (Moeur 1985) has been developed as an extension of the Stand PROGNOSIS model (Wykoff *et al.* 1982) for predicting shrub community development in several habitat types of Washington, Idaho, and Montana. The results of the data collection and modeling activities in adjoining northern U.S. states should be useful in the development of models which can be applied to ecosystems in the southern Interior.

Models to evaluate the consequences of alternative treatment strategies on forest yield, economics, and environmental impacts are currently being developed. FORCYTE-11 (Kimmins 1988; Kimmins and Scoullar 1989) is one such model which incorporates the simulation of competition for light and nutrients between crop and non-crop species, site effects on forest yield, and the effects of management activities on yield and economic returns. Other models such as TASS (Mitchell 1975) and PROGNOSIS (Wykoff et al. 1982) have the potential to be developed for use in vegetation management research and gaming. However, these latter two models currently lack any representation of competition between crop and non-crop vegetation and they do not consider site nutrient effects.

5.1.3 Management

Eight projects are directly addressing management of brush communities in the southern Interior (FRDA projects 3.21, 3.40, 3.41, 3.44, 3.46, 3.59 3.60, and 3.62). These projects are demonstrating the use of mechanical, manual, herbicide (glyphosate hexazinone, 2,4-D, triclopyr), biological, and fire treatments for controlling competing vegetation and improving the establishment and growth of conifer seedlings. The efficacy of mechanical, manual, and chemical brush control techniques are also being investigated in connection with several other FRDA projects and in connection with SX and other trials. Information on species responses to treatments has been summarized by Coates and Haeussler (1986), and the effectiveness of chemical control in similar areas of the U.S. has been described by Conard and Emmingham (1983, 1984). The use of natural pathogens for biological control of major brush species is also being investigated (FRDA 3.59).

5.1.4 Environmental Impacts

Studies of the impacts of vegetation management activities on site quality, particularly as related to soil conditions, have been initiated in the Interior Cedar Hemlock Zone. Results of long-term monitoring of treated sites will be useful in the development, calibration, and validation of models used for predicting impacts. Studies of impacts on range values are also currently under way. However, no studies of impacts of vegetation management activities on other resources are presently being supported under FRDA funding in the southern Interior. A review of the effects of forest herbicides on wildlife forage species in British Columbia was completed during 1987 (Balfour 1987) and a model is being developed using the results of this survey.

Demonstration sites established in the ICH (FRDA 3.44) and ESSF (FRDA 3.41) should provide benchmark sites for assessing long-term impacts.

5.1.5 Development of decision support tools

Several field guides have been prepared for the province and are applicable to the southern Interior. Notable of these are publications prepared by Haeussler and Coates (1985) and by Coates and Haeussler (1986). Such synopses of information are useful for guiding operational decisions. Data from several studies being conducted both within and outside the province should be useful in the development of additional handbooks and other tools (such as models and "expert systems") which can aid forest resource managers.

5.2 Research Needs

Operational forestry staff require tools for assessing and predicting forest vegetation management problems. Decision support tools are also needed to guide the implementation of environmentally and economically sound management decisions. Research needs include the acquisition of basic information, and the development of tools for integrating and applying this information in operational stand and forest management. Several gaps in the FRDA research program are evident from an examination of Table 5.1.

5.2.1 Assessment

Diagnostic tools for assessing the origin of regeneration failures and the effects of vegetation on crop growth are required. The development of such tools will depend on an understanding of the factors which cause regeneration failures and which inhibit seedling growth and establishment in the diversity of environments present in the southern Interior. The focus of research in this area should be on the development of diagnostic tools such as competition indices or models, and diagnostic systems for identifying the origin of regeneration failures. Development of these tools depends on the existence of suitable research information. Research should aim to provide the data base required for the development of decision support tools such as field handbooks and microcomputer "expert systems" and models.

Additional studies of interference with crop tree seedlings by non-crop vegetation are required in all complexes and in all zones. Studies may be required in the fern, wet alder, dry shrub, mixed hardwood, aspen, cottonwood, and domestic complexes if studies being conducted elsewhere are not appropriate to local conditions. There is a need for empirical studies of seedling survival and growth relative to abundance, proximity, and height of non-crop vegetation; and for studies which examine the nature of competition and interference, and the physiological responses of seedlings and trees to interference. "Empirical" studies are useful in that a large number of sites can be sampled; process-oriented studies must usually be restricted to a smaller number of study sites. However, process studies provide information which can be generalized to other locations, while empirical studies are often site-specific and site condition-specific, which often limits the extent to which the results can be generalized.

Research projects should also be initiated to evaluate the beneficial roles of early seral species to seedling microclimate and to site condition. The influence of early seral communities on soil biology (e.g., mycorrhizae, root rot fungi) should also be investigated, as should physical and chemical interference in selected complexes.

5.2.2 Prediction

The selection of appropriate harvesting, site preparation, and regeneration methods will substantially reduce future backlog problems. Selecting appropriate treatments or combinations of treatments requires the ability to predict the effects of treatments on vegetation development, crop establishment, and crop growth. Models are useful for making such predictions. The development and verification of appropriate models requires data from field research.

The effects of harvesting, site preparation, and brush control activities on the characteristics of early seral communities are receiving only limited attention in the southern Interior. Current research on the effects of brush control on vegetation development should be continued and expanded, and research on vegetation development following harvesting and site preparation should be initiated. Empirical data on changes in species composition, abundance, and height over time should be acquired in connection with permanent installations established before harvesting. Replicated trials should be established in major ecosystems where vegetation management problems are anticipated. Data from such permanent installations should be useful in several aspects of forest yield modelling, research, and environmental impact assessment.

Understanding processes involved in succession will aid foresters in developing appropriate treatments, in predicting the consequences of new treatments, and in extrapolating results of empirical models to other, similar environments. Studies of autecology, plant population biology, and community dynamics are needed for key sites and major complexes in the southern Interior. These

studies should be linked with empirical trials to provide maximum returns from both types of research, but they may have to be limited to a subset of the empirical trials.

Information should be collected to develop simulation models as tools for predicting vegetation development following harvesting, site preparation, and vegetation control activities. A protocol for the design of such studies should be developed before any major projects of this nature are begun. Such a protocol should be developed following consultation with several individuals and agencies interested in the prediction and modelling of ecological succession and forest yield.

5.2.3 Management

Operational and research trials of potentially useful management techniques have already been established in many of the major problem vegetation complexes in the southern Interior or other areas of British Columbia. A thorough review of existing trials is required to identify possible deficiencies in mechanical, manual, chemical and biological approaches to controlling vegetation. Results from these trials should be summarized and made available to managers and researchers. A summary of vegetation control research in the Ministry of Forests is being initiated by the Research Branch.

Vegetation management must be integrated with other components of rotation-length stand and forest management systems. The evaluation of management options requires consideration of short-term and long-term responses of crop plants to release, and of the economics and environmental impacts of management activities. Assessment of costs and benefits of vegetation management alternatives should be conducted over a rotation or longer. Such assessments require ecosystem-level models which consider the effects of site factors and vegetation interference on tree establishment, survival, and growth, and which tie these factors to evaluations of the economics and impacts of alternative treatments within a rotation length silvicultural system. The FORCYTE series of models (Kimmins 1986, 1988; Kimmins and Scoullar 1989; Kimmins and Sollins 1989) has these capabilities.

5.2.4 Impacts of treatment

In addition to ongoing studies of the impacts of vegetation control on succession and soil resources, studies of impacts on other resources should also be undertaken (e.g., wildlife, water, recreation).

5.2.5 Decision support tools

Research results provide the "decision support data bases" needed for the development of treatment prescriptions. To be most useful to forest managers, research results must be integrated into handbooks, computer simulation models, and computerized decision support systems ("expert systems"). Tools such as these are extremely valuable for implementing research findings, consolidating existing information, and identifying priority areas for further research.

5.3 Summary

Vegetation management research projects have been completed or are under way in 9 of the 14 vegetation complexes present in the southern Interior. Studies are largely focussed on individual topic areas and cover a limited range of sites. Areas of research include competition studies, succession studies, studies of vegetation control techniques, and studies of the impact of vegetation management on site resource availability and range resources.

To be most useful to operational forestry staff, research should focus on the development of tools which will assist in the development and evaluation of vegetation management prescriptions. This requires basic research information, consolidated into a particular tool. Systematic development of tools such as field handbooks, simulation models, and "expert systems" will also help to identify critical research needs.

Additional and continuing studies of competitive interactions between crop and non-crop vegetation are required in all complexes and all zones. Such research should be directed towards the development of techniques for assessing vegetation management needs and for identifying responses of crop seedlings to treatment.

The collection of information on vegetation development following harvesting, site preparation, and vegetation control should be directed towards the development of simulation models for predicting vegetation development. The modelling approach and the model selected will largely determine information needs and the design of further research on community succession.

Studies of a range of available vegetation control techniques are under way in many of the vegetation complexes represented in the southern Interior. A review of vegetation control research should be conducted at the provincial level to identify critical needs and future directions. In addition to research on impacts of vegetation control on site quality, studies may be required to deal with treatment impacts on other resources. These studies should be integrated within the framework of other studies aimed at evaluating treatment alternatives or monitoring vegetation development.

SECTION 6

A FRAMEWORK FOR VEGETATION MANAGEMENT RESEARCH

It can be argued that the "scientific method"[6] is not appropriate as the sole basis on which to advance knowledge in either basic or applied ecology. A necessary and vital component of advancing the more mature disciplinary sciences, the scientific method certainly has an important role to play in ecological research. However, if applied dogmatically, it can hinder rather than help in attaining the central goal of ecology: namely, to understand and predict ecosystem structure and function, and the changes within it. Scientific reductionism in ecology contributes to our understanding of individual processes and components of ecosystems, but it can inhibit our understanding of the interdependency of these components and processes, and the synthesis and systems approach which is central to the science of ecology.

The same can be said about applying the scientific method to research in many aspects of forest ecology and silviculture. Predicting the productivity, the temporal dynamics, and the response to management of a forested landscape requires an ecosystem-level approach which integrates the effects of all the major ecological processes active in that landscape during the crop rotation. Reductionist forest science is necessary to help us understand of the individual components and processes involved and how forest management activities affect these in the short term. However, research on individual ecosystem components or processes cannot provide an adequate assessment of the overall long-term consequences of a particular management practice unless the results are integrated into an ecosystem-level, rotation-length evaluation of the practice.

Research in vegetation management has the overall objective of manipulating the structure, composition and productivity of the forest plant community to maximize the attainment of management goals. Because the timber management component of those goals generally refers to the quality, size, value and quantity of the timber crop at the end of the rotation, vegetation management research should be conducted within an ecosystem framework, and within the context of rotation-length silvicultural systems. This suggests the need for research protocols which will ensure that vegetation management research is conducted within the appropriate philosophical and temporal frameworks. It also suggests the need for research tools that can integrate the results of individual research projects over the appropriate temporal and complexity scales. This section of the report examines the need for an ecosystem approach in vegetation management research, and for research protocols to ensure that the products of this research are useful decision support tools as well as the more conventional results of scientific research.

6.1 The Framework for Vegetation Management Research

Vegetation management has traditionally focussed on populations or communities of weed species, and on individuals and populations of crop species. Where the major determinant of crop species survival and growth is the interactions between crop and non-crop species, this focus may be appropriate. However, where these biotic interactions are affected by abiotic conditions, and where abiotic parameters are significant determinants of crop species performance, an ecosystem-level approach is more appropriate.

Vegetation management research should be conducted in an ecosystem framework, and as a component of rotation-length silvicultural systems. The traditional view that the objective of vegetation management should simply be to deliver a well-stocked, "free growing" plantation to the stand manager is not acceptable. This objective should be modified to require (1) that the ecosystem be in a condition to optimize growth over the remainder of the rotation, and (2) that the vegetation management be considered in the context of the overall rotation length stand management system. Only in this way can we optimize the economics of rotation-length stand management.

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[6] The "scientific method" is widely interpreted as being synonymous with the "hypothetic-deductive" method of science. The latter involves the development of a reductionist, refutable hypothesis based on existing knowledge of a phenomenon, process or object of interest, the testing of this hypothesis in a definitive experiment, and the rejection or support of the hypothesis (or null-hypothesis) on the basis of the experimental results. Many authorities on the scientific method exclude inductive and descriptive research from the definition of "true" science.

6.1.1 Ecosystem framework

An ecosystem rather than a population or community approach is necessary for assessing and predicting vegetation management problems because these problems exist in ecosystems, not isolated in populations or communities. The future state of a forest ecosystem is the combined result of a complex of biotic and abiotic influences, the relative importance of which varies from site to site and over time. Only if all significant determinants of ecosystem structure, function and dynamics are considered can one hope to assess accurately the nature of present crop - non-crop plant interactions, or predict future interactions. Unless accurate assessments and predictions can be made, it is difficult to avoid making errors in prescribing vegetation management treatments, errors that may be very costly when considered over the whole rotation.

The major implications of accepting an ecosystem framework for vegetation management research are:

1. that all vegetation management research and prescriptions be done on a site-specific basis, using the biogeoclimatic classification framework.
2. that all research projects monitor a basic set of climatic, edaphic and biotic parameters and so improve our ability to identify the roles of biotic and abiotic factors (and their interactions) in determining the early and long-term growth performance of crop trees.
3. that the results of conventional process-oriented and empirical research be used in conjunction with tools of synthesis ("decision support tools," which may be field guides, keys, or computerized decision aids) so that the complexity of the ecosystem can be handled. Computer models offer the one way in which the complex knowledge of how ecosystems work (the product of research) can be used to assist forest managers in their vegetation management decisions. Computerized "expert systems" offer a method for harnessing the extensive field experience of practising forest managers and researchers into practical, field-oriented management decision tools.

6.1.2 Vegetation management as a component of rotation-length silvicultural systems

Vegetation management is often considered to be an activity relatively isolated from other components of the rotation-length silvicultural system. Because economic investments in vegetation management are made early in the life of the crop, they have important implications for the present net value of the crop.[7] Such investments should therefore be made carefully, and only after the ecological and economic implications of a variety of alternative treatments and rotation-length treatment combinations have been evaluated. For example, elimination of nitrogen-fixing alder from a site may increase short-term tree growth, but on some sites it may increase the need for nitrogen fertilization later in the rotation. Eliminating seedling mortality by eliminating all weed competition may increase the need for subsequent stocking control.

If we accept that vegetation management research and practice should be considered in the context of rotation-length silvicultural systems, then we must develop and use computer models that are capable of predicting: 1) the growth and interactions of crop and non-crop vegetation; 2) the effects of resource availability on these interactions; and 3) the consequences of all the major vegetation management and silvicultural treatments. Without such models, believable rotation-length evaluations will be extremely difficult.

6.2 Research Protocols for Vegetation Management

The Herring and Pollack (1985) and Pollack and Herring (1985) research protocols provide an excellent basis for the field layout and establishment of trials of vegetation control techniques. However, the focus of these protocols is on testing the short-term efficacy of treatments on target weed species and the short-term response of the crop trees. The final required assessment is at five growing seasons' post-treatment, and although the authors' note that further assessments may be made at the discretion of the

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[7] Present net value (PNV): the sum of all future silvicultural costs and revenues, discounted to the present at some chosen discount rate. The "internal rate of return" is the discount rate at which PNV is zero.

researcher, they do not discuss the time scales over which it might be appropriate to continue the assessments. In some cases, 5 years of assessment may be adequate as the basis for predicting the rotation-length consequences of the treatments. In other cases, two or three decades may be required for a full assessment of the treatment effects. Some treatments which might be very effective over a 5-year time scale (e.g., mechanical site preparation, broadcast slashburning) may only prove to be optimum over the whole rotation if combined with subsequent treatments, such as fertilization. In such cases, a complete evaluation of the initial treatment can only be made in the context of the overall rotation-length silvicultural *system* of which the initial treatment is but a component.

The Herring and Pollack protocols are concerned mainly with the evaluation of weed control treatments. They do not deal with two other important areas of vegetation management research: assessment of vegetation management problems, and prediction of the future development of crop and non-crop vegetation, with and without management treatments. Details of the protocols needed to guide research on assessment and prediction are beyond the scope of this report, but the following two sections discuss areas of research for which appropriate protocols are needed.

6.2.1 Research related to the assessment of vegetation management problems

Accurate assessment of whether or not there is a vegetation management problem on a site, and what the nature and extent of the problem is if it exists, requires an understanding of the factors that are acting to limit the growth of the crop trees on the site. The nature and extent of interactions between crop and non-crop plants should be identified and separated from the environmental characteristics of the site.

In some environments in British Columbia, low soil temperature, short frost-free growing season, high summer temperatures, and climatically and edaphically determined summer moisture deficits may singly or in combination limit the growth of young crop trees. The magnitude and dynamics of soil organic matter and associated soil nutrient pools also have a strong influence on the growth of crop trees. Where abiotic physical or chemical site parameters act to limit crop tree growth, modification of the non-crop vegetation may give disappointing results.

Research concerned with developing techniques for assessing vegetation management problems should therefore include the following:

1. Assessment of the potential climatic and microclimatic limitations to crop tree growth.

This should include the estimation, from existing data, of parameters such as heat sums, frost-free growing season, snow-free growing season, boundary-layer radiation frosts, summer soil moisture deficits, vapour pressure deficits, and radiation loadings. These estimates should be compared with the known autecological tolerances and requirements of the crop trees of the age and physiological condition involved.

2. Assessment of the potential soil nutrient status and the probable temporal pattern of nutrient availability.

This should include a qualitative assessment of trophotope (using standard Ministry of Forests procedures), of reserves of mineralizable nitrogen, of the likelihood of deficiencies of other nutrients (based in part on soil mineralogy and coarse fragment content), and of the extent and duration of an "assart" nutrient flush.[8] A comparison between the known nutritional requirements of the crop trees and this assessment of nutrient availability may suggest that nutrient limitation is a significant contributor to poor initial crop tree growth performance on the site in question. Site nutrient conditions should therefore be quantified and monitored in any vegetation management research plots established on the site. Small-scale fertilizer response screening trials may be useful, although the long-term site fertility may be wrongly estimated by this technique if the analysis is done during the assart period.

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[8] The "assart" nutrient flush is the period of increased nutrient availability which commonly occurs following the removal or disturbance of the previous plant community. The assart flush is associated with a period of accelerated organic matter decomposition, which in turn is related to changes in temperature, moisture and microbial conditions in the forest floor and upper mineral soil.

3. Where climatic and edaphic conditions are not considered to be the major factors limiting crop seedling performance, establishment of research plots to determine the extent and nature of any crop - non-crop plant interactions that may be limiting crop tree growth.

Determining the nature and extent of competitive and other crop - non-crop species interactions is difficult and may be very costly. The classical additive and substitutive designs that have worked well in research on competition/interference in agriculture and ecology (mostly on herbaceous communities) may not work as well in forestry. The larger size of forest crop plants, their relatively slow growth, and the much slower growth response of evergreen perennial species in comparison to annual or deciduous perennial species may make the "neighbourhood experiment" design more attractive than these conventional designs. "Neighbourhood experiments" are simply a form of additive experiment, in which the growth of crop trees relative to the degree of interaction with non-crop species is examined on an individual tree basis. In such experiments, existing natural variation in plant communities can be used, (or the amount of existing non-crop vegetation can be manipulated to varying degrees) and then individual seedling growth performance can be monitored under a range of intensities of competition. The design can be imposed on an existing plantation, or can be set up at the time of plantation establishment (e.g., in the form of a nelder[9] plot).

We recommend that a protocol for research to assess the extent and nature of competition/interference be developed. Guidelines are needed for the establishment and long-term monitoring of experiments designed to develop an improved understanding of competitive and other interactions between crop and non-crop species.

6.2.2 Research related to the prediction of vegetation management problems

Herring and Pollack (1985) divided forest vegetation control strategies into: 1) the site preparation strategy; 2) the stand establishment strategy; and 3) the stand release strategy. The site preparation strategy involves the prediction of non-crop vegetation development (succession) with and without treatment, while all three strategies require predictions of their medium- and long-term consequences. Economic evaluation of vegetation management strategies requires the ability to predict the effects of the strategies on the volume and value of the crop trees at the time of harvest. This requires that the effects of vegetation management on stand growth and dynamics be accurately predicted over periods as long as many decades.

Prediction of succession and of the long-term consequences of vegetation management for stand development and yield can be approached in three different ways:

1. Empirical approach: This involves either the description of vegetation development on chronosequences of areas that vary only in the time since disturbance, or similar descriptions obtained from permanent sample plots established before disturbance and monitored for several decades after disturbance. The advantage of the chronosequence approach is that the descriptions are obtained more rapidly than from long-term studies; the disadvantage is that the different aged sites may not have had the same history and may not have been identical originally. Consequently they may not represent the true temporal pattern of vegetation development for a given site/disturbance combination (Hamilton and Yearsley 1988).

Because of the shortcomings of the chronosequence approach, empirical research on predicting vegetation change should include the establishment of a system of long-term (at least rotation-length) succession monitoring plots. These can be existing SX or RX trials, chronosequence sites (as described above), or other research plots upgraded to long-term status, with appropriate (i.e., concrete, metal or treated wood) corner posts and metal information plates. Alternatively, these plots can be established specifically for this purpose.

Empirical descriptions of vegetation change are a model of the expected patterns of succession and stand development for particular sites following particular types of disturbance and/or vegetation management. Such empirical models can provide a satisfactory basis for predicting the development of future vegetation problems, and the yield and economic consequences of treatment strategies, but

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9 A "nelder" plot is a plantation designed like the spokes of a wheel. The spacing of trees planted along any "spoke" is the same as the distance between "spokes." This is a space-efficient way of examining the effects of stand density/competition, but it may pose some statistical problems in the analysis of the resulting data.

only for future treatments, site conditions, and/or biotic events that are similar to those associated with the development of the empirical models. Consequently, representative chronosequences would have to be located in every representative ecosystem unit for which such information is desired.

2. Process simulation approach: This involves using our knowledge of the life histories and growth strategies of plants, of the processes of growth, resource competition, and other interactions between crop and non-crop plants, and of soil and climatic processes and effects to predict the development of the vegetation under a defined set of future environmental conditions. These future conditions are those expected to result (based on empirical evidence or simulation) from a given type of disturbance or vegetation management treatment.

Such simulation models can permit the development of interim predictions by which the desirability of alternative vegetation management strategies can be ranked. These interim predictions are necessary as an adjunct to the results of chronosequence research, and as an alternative to the results of long-term successional and stand development monitoring, until such results are available. The particular data requirements will depend on the choice of simulation model and cannot be defined until a model has been selected or developed.

3. Hybrid simulation approach: Attempts to produce simulation models based solely on our understanding of ecosystem processes have been limited in their success. This failure can be variously attributed to our lack of adequate knowledge of the processes involved, our failure to include in such models all relevant processes which we do understand, or our inability to represent all the knowledge we do have without such models becoming too complex to use. However, the combination of the empirical approach and the simulation approach into hybrid simulation models (Kimmins 1986) appears to offer a significant advance over either of the two component approaches, and can result in useful management planning and research tools. Ecosystem-level simulation models generally require very large and complex data bases, and are therefore limited in their usefulness and generality. The hybrid simulation approach has less demanding input data requirements, and models of this type can provide practical decision support tool with which certain types of vegetation management questions can be assessed.

Research concerning the prediction of vegetation development and the long-term consequences of various vegetation management strategies should use whichever of these three approaches appears to be the most practical and effective. Protocols should be developed to ensure the efficacy of the various approaches.

6.3 The Need for Tools of Integration and Synthesis

Forest science of the past 50 years has been successful in filling libraries with a rapidly accumulating volume of information about all aspects of forests, from remote sensing to detailed soil processes. Unfortunately, much of this knowledge is of more value to other forest scientists than it is to forest managers. This relative lack of practical value does not imply lack of scientific rigour, accuracy or relevance of the research. It has more to do with the fact that the scientific information produced by researchers has tended to be at temporal and spatial scales that are different to those of the problems faced by foresters in their daily work (Baskerville 1986). That such time and space scale gaps exist is an almost inevitable consequence of the increasing application of the "scientific method" (as discussed above).

The answer to this problem of "technology transfer" from research scientists to forest managers is not to change the research strategy of all the scientists, but rather to develop mechanisms by which the results of the research can be translated into the time and space scales appropriate for management. A variety of mechanisms can be used, referred to collectively as "decision support tools." These may be field guides, field keys, computerized "expert systems" or computer simulation models. More will be said about these in Sections 7 and 8.

6.4 Summary

The major arguments presented in this section are:

1. The traditional "scientific method" has much to contribute to vegetation management research, but the reductionist science that results from the strict application of this methodology is insufficient on its own as the framework for vegetation management research.

2. Vegetation management research should be conducted in an ecosystem framework to improve the accuracy with which we can assess crop - non-crop vegetation interactions, and can predict succession, the future development of vegetation management problems, and the long-term consequences of vegetation management treatments.

3. Vegetation management and research should be conducted in the context of rotation-length silvicultural systems, and stand-level, rotation-length economics.

4. Research protocols should be developed that describe the general research strategy to be adapted for research on assessment and prediction in vegetation management.

5. Tools of integration and synthesis must be developed to bridge the time-scale and space-scale gaps that exist between conventional scientific research and vegetation management practice. A variety of tools can be used, but hybrid computer simulation appears to offer significant advantages for yield and economic predictions.

SECTION 7

A VEGETATION MANAGEMENT RESEARCH STRATEGY FOR THE SOUTHERN INTERIOR

In proposing this research strategy, we recognize that a great deal of thought has already been given to the topic by many experienced and well-qualified individuals. We intend no criticism of existing plans of vegetation management research in the southern Interior. Differences between the strategy described below and that in previous proposals reflect differences in the background and perspectives between the authors of the present report and those who have designed and implemented the existing program.

In this section, we propose an outline for a strategy of vegetation management research in the southern Interior.

7.1 Objectives of the Research Strategy

A strategy is a plan of action, requiring both overall (strategic) and specific (tactical) objectives.

7.1.1 Overall (strategic) objectives

The following are proposed as the overall objectives of the research strategy presented here:

1. To develop tools of vegetation assessment: to develop a combined field/office assessment methodology that can be used throughout the southern Interior to answer, on a site-specific basis, the questions:

   (a) What are the causes of regeneration failure? Is failure related to non-crop vegetation or to some other site-related condition (e.g., climate, seed predation, poor stock quality or planting, etc.)?

   (b) Is the present net balance of positive and negative interactions between crop and non-crop plants sufficiently negative to justify management actions now or in the near future?

   (c) Could existing or potential problems arising from interactions between crop and non-crop plant species be eliminated or overcome by the use of different species, planting stock, stock quality, or stock size and age? (Although not strictly a vegetation management topic, this question must be included here because many vegetation management problems may be related to the use of the incorrect species, stock type, stock age, stock condition, etc.).

2. To develop tools of prediction for vegetation management: to develop a combined field/office prediction methodology that can be used throughout the southern Interior to answer, on a site-specific basis, the following questions:

   (a) Will interactions develop in the future between crop and non-crop plant species that are sufficiently negative to justify preventative management actions now or in the near future — or remedial actions in the more distant future which should be planned for now?

   (b) What are the probable consequences of a variety of alternative vegetation management treatments for short-term crop tree growth, for rotation-length timber yields and economics, and for other site values such as wildlife/range carrying capacity, soil fertility, and long-term (multi-rotational) site productivity?

3. To develop effective vegetation management treatment methods: to develop a range of vegetation management treatment alternatives for problematical plant communities on economically important sites in the southern Interior. These alternatives should include chemical, mechanical, manual and biological treatments, the use of prescribed fire, and various combinations of these treatments. The research should also contribute to the development of a methodology by which the long-term consequences of alternative site and vegetation treatments can be predicted (see 2(b) above).

7.1.2 Specific (tactical) objectives

The following specific objectives are proposed:

1. Specific objectives of assessment research

   (a) To develop decision support tools in the form of field guides, competition indices, physiological/morphological indicators of competition intensity, and/or computerized decision support systems (e.g., "expert" systems), to improve our ability to assess the need for vegetation management treatments (i.e., when is interference from non-crop vegetation a major factor limiting crop tree performance?) and to identify priority areas for treatment.

   (b) To develop decision support tools (as above) to assess the degree to which alternative regeneration strategies could be substituted for vegetation management treatments.

   (c) To develop training packages and systems for the delivery of decision support tools, to guide field staff in their use for assessing the need for vegetation management treatments.

2. Specific objectives of prediction research

   (a) To design models of vegetation development for all the major vegetation management problem site types in the southern Interior, with and without various vegetation management treatments. These models, which may be presented graphically, pictorially, verbally, or by computer, should permit accurate predictions about the future development of vegetation management problems, and about the need for, and outcome of, preventative or remedial treatments.

   (b) To develop a data base from a series of permanent plots of vegetation development representing the major vegetation management problem site types in the southern Interior.

   (c) To develop the simulation models as a method by which to integrate the results of diverse vegetation management and other silvicultural research projects. The resulting models are to be used to assess vegetation management strategies as a component of overall rotation-length silvicultural systems, and to make economic evaluations of vegetation management treatments.

   (d) To develop the simulation models for use in predicting the long-term consequences of alternative vegetation management strategies for wildlife and range values, for water quality, for soil fertility and for long-term site productivity.

3. Specific objectives of management treatment research

   (a) To develop effective, economical, and environmentally acceptable methods of non-crop vegetation control.

   (b) To provide a comparison and field demonstration of the efficacy of alternative vegetation management treatments in improving short- and long-term crop growth, yield and value.

   (c) To provide data to evaluate the empirical and hybrid simulation vegetation management prediction models that are required to satisfy the objectives defined in 2 above.

7.2 A Strategy for Vegetation Management Research

The proposed research strategy has two major components:

1. suggestions for the expansion and modification of existing projects.
2. suggestions for the initiation of new projects.

7.2.1 Expansion and modification of existing projects

- There are several current projects which will contribute significantly to the development of assessment techniques. These include competition studies (e.g., neighbourhood experiments) and studies of the effects of vegetation on environmental conditions. Treatment trials in which competition has been removed to various degrees and crop seedling response is being monitored can also be valuable. This type of research should be expanded to cover all the major problem vegetation complex-site type combinations identified in the southern Interior. The design of these studies and of the current studies should conform to a competition Assessment Research Protocol, to be developed as soon as possible. The research should demonstrate for each of these vegetation complex-site type combinations the relative importance of interference from non-crop vegetation in limiting the growth of the crop trees. It should also identify useable competition indices, and crop tree morphological/ physiological indicators of the degree of interference from non-crop vegetation. The product of these research projects will satisfy the specific objectives of the assessment methodology research. Basic studies aimed at improving our understanding of the nature and effects of these interactions should be undertaken in conjunction with some of these studies.
- Additional studies of community succession should be undertaken so that empirical models of secondary succession can be developed for the major vegetation complex/site type/disturbance type combinations of the southern Interior. It will not be possible to cover all such combinations, and wherever possible the expanded studies should be established in existing SX or RX trials or research plots. The design of these expanded studies, and of the current studies should, wherever possible, conform to a Prediction Research Protocol, to be developed as soon as possible. As a minimum, the research protocol should ensure that sufficient data are collected on the growth and life history of the individual non-crop species and that their role in secondary succession is adequately described. In addition to developing the empirical models, this research should also provide a variety of calibration data for the simulation models. Such computer models may be needed until data are available from long-term permanent sample plots, and, once validated, such a model could be used to make predictions for vegetation/site/treatment combinations for which there are no chronosequence data (i.e., no empirical model). Many of the chronosequence sites may also be suitable for long-term permanent sample plot status.
- Existing studies of non-crop vegetation control methods should be expanded to additional vegetation/site combinations where needed. A review of existing trials and information should be conducted to identify key target species, sites and treatments needing further study. These trials should compare different treatment approaches (chemical, mechanical, fire, biological, manual), as well as different rates and timings of chemical controls. The scope of these management trials should be expanded so that they can provide data on the long-term effects of alternative treatments. Some of these management trials could develop in conjunction with long-term permanent sample plots.

7.2.2 New projects

New projects are recommended in three areas.

- Available information and experience concerning the assessment, prediction and management of non-crop vegetation should be assembled and used in the development of one or more decision support tools. It is suggested that these include printed field guides for the assessment, prediction, and control of vegetation management problems (e.g., Coates and Haeussler 1986). Material incorporated into these provisional field guides could be used in the development of a computer-based "expert system," if necessary. Such computer systems would allow easy and rapid access to much larger data bases than printed field guides can, and would provide a much more detailed decision support tool.
- A review of existing computer models which might be suitable for development as a vegetation management simulator for the southern Interior should be undertaken. The ideal model should include an ecosystem-level representation, deal with different vegetation life forms (herbs, shrubs, trees) and competitor types, and competition for site resources

(nutrients, light, moisture), and should be able to simulate all major vegetation management and silvicultural practices. The model should predict productivity, yield, rotation-length stand level economics, soil fertility and the sustainability of site productivity. If no model is identified as being suitable for direct application, an existing model should be modified or a new model developed. Data for the calibration of the model would be provided from existing and specially commissioned research projects. To validate them, the model's predictions would be compared to the results of appropriate field research projects.

- A series of training course and extension materials should be developed which summarize existing knowledge of vegetation management and provide training in how to use the decision support tools and other results of vegetation management research.

7.3 Concluding Statement

It is the intent of this research strategy that the existing program of problem-specific and more general (basic) research be continued and expanded to cover all the major vegetation complex/site type combinations of the southern Interior. The strategy proposes a framework within which this work can be conducted. This framework will provide research protocols which will facilitate the synthesis of various research results into a series of periodically updated decision support tools. These tools are the end product of the research program, and provide an improved means by which foresters can assess and predict vegetation management problems, and prescribe preventative or ameliorative vegetation management treatments. These tools will also aid in the transfer of research results to operational forestry staff, and in identification of further specific regional needs. The final section of this report expands on methods for ensuring the transfer of these tools to field foresters.

SECTION 8

IMPLEMENTATION OF RESEARCH RESULTS IN OPERATIONAL VEGETATION MANAGEMENT: A STRATEGY FOR "TECHNOLOGY TRANSFER"

Research in vegetation management is unlikely to result in any improvement in regeneration and stand growth unless the research results are successfully communicated to forest managers in a format they can understand and use. The need for developing decision support tools was made clear in the questionnaire responses (Section 3).

An excellent example of the importance of technology transfer is the user-training program developed by the Biogeoclimatic Ecological Classification program of the Ministry of Forests. The major product of the ecological classification program has been a series of decision support tools in the form of tree species selection and slashburning guides, site identification and interpretation guides, and plant identification guides. The development of these field tools has been accompanied by an aggressive program of field training sessions in which the guides have been explained and demonstrated both in workshops and on field trips. We believe that a similar strategy should be adopted in vegetation management.

8.1 Strategy for Technology Transfer

We propose that high priority be given to the component of the research strategy dealing with decision support tools: field guides, computerized "expert systems," and simulation models. The considerable wisdom that has been accumulated by researchers and operational foresters concerning the assessment, prediction and management of non-crop vegetation problems must be captured and presented in a format which facilitates improved operational practice in vegetation management. However, development of these tools is not sufficient in itself. It must be accompanied by a program of annual workshops and training programs. The format of these should include a series of introductory lectures that summarize current knowledge of vegetation management and present the decision support tools. These sessions should include field trips to demonstration and research sites where exercises can be given in site assessment, prediction and prescription development.

Training sessions should be offered in each district to provide local foresters with up-to-date information on the results of vegetation management research. Such training programs should be developed and co-ordinated at the provincial level.

In addition to the workshops, tape-slide shows and video presentations should be developed so that material presented in the workshops can be reviewed; and printed summaries of relevant research results and handbooks should be made available. Training materials could also be used in various forestry education and information programs around British Columbia.

8.2 Concluding Statement

Intensive forest management, in which increased yields are expected from less land, will require that as much of a site's resources be made accessible to crop trees as possible, commensurate with sustaining the ecological integrity, the sustainable productivity, and the non-timber resource values of the site as defined by the area's management objectives.

This will require that forest managers be equipped with "state-of-the art" knowledge and tools so that they can make economically, ecologically and silviculturally correct decisions about how best to manage non-crop vegetation. As the results of vegetation management research accumulate, it will become increasingly important that these results be packaged and delivered to forest managers quickly and effectively. Development of decision support tools and an extension program to train foresters in their use will ensure that the results of vegetation management research are applied in the field.

SECTION 9

RECOMMENDATIONS AND IMPLEMENTATION

As useful as any program of individual research projects might be, the full value of such work can only be realized if the individual projects are co-ordinated within, and contribute to, a single, well-focussed goal. The goal of the vegetation management research program in the southern Interior should be the production of a series of management tools by which we can improve the assessment and prediction of vegetation problems, and the prescription of preventative or ameliorative treatments. Although many of the individual projects in the research program should continue to focus on specific problems or questions, all projects in the program should be designed and conducted in a manner that contributes to the achievement of the overall goal of the program. In this final section, we present our recommendations and suggest a timetable for the implementation of the proposed research strategy.

9.1 Recommendations

1. That vegetation management research in the southern Interior be organized within an overall research framework that has as its goal the development of operational vegetation management tools (decision support tools).
2. That these tools include field assessment, prediction and management guides, a computerized "expert system" to provide a more detailed evaluation of field decisions, and computer simulation models with which long-term predictions and economic assessments can be made, and the results of diverse field research projects integrated.
3. That research protocols be developed that will ensure existing and new research projects do provide the necessary data bases for the calibration or the evaluation of these decision support tools.
4. That new research projects be initiated to provide data and knowledge needed for the development of the decision support tools.
5. That a system of long-term permanent sample plots be established to provide empirical data on the long-term consequences of vegetation management.
6. That many of the existing research projects be replicated on other problem vegetation complexes that have not yet been adequately researched.
7. That a major effort be made to transfer the knowledge and management tools developed by this research program to the operational forest managers for whom they are intended. This will involve a sustained program of workshops and training sessions, and the development of a variety of communication packages (manuals, tape-slide shows, videos, and computer-based management gaming tools).
8. That the vegetation management research program and vegetation management decisions be integrated into the overall stand-level, rotation-length, silvicultural systems of which they are but a component. This will require the development and use of ecosystem-level, rotation-length management simulation models.
9. That vegetation management decisions be made for whole-forest (Timber Supply Area) as well as stand-level forest management. This suggests that the stand-level decision support systems referred to in this report should be integrated with a Geographical Information System or some other whole-forest model.
10. That vegetation management needs and the goals of vegetation management research be reviewed periodically to ensure that any research strategy adopted in the southern Interior is still relevant and focussed on the production of management tools that are needed and that are available at the time.

9.2 Implementation of the Recommendations

Because this report recommends that all vegetation management research in the southern Interior have a common goal and be conducted within a single framework, the details of this framework must be established without delay. The logical sequence of activities that should be undertaken are:

1. Prepare lists of existing types of "expert systems," computer simulation models, and vegetation management field handbooks that could be candidates for selection as the decision support tools that will provide the integrating framework for the research program.
2. Evaluate and select from these lists candidate decision support tools that will become the basis for the research program.
3. Design research protocols that will ensure that the program of vegetation management research will generate knowledge and data that can be used to develop, calibrate (provide a data base for), and validate (test or evaluate) these tools.
4. Evaluate the extent to which existing or past research projects and operational field experience can provide the necessary databases for the development and evaluation of these tools.
5. Initiate research projects to fill data and knowledge gaps.
6. Validate of the first approximation of the decision support tools.
7. Distribute and demonstrate the validated decision support tools.
8. Refine and develop these decision support tools as new knowledge and data become available, and as new management needs are identified.
9. Design and implement new research projects as the continuing development of the decision support tools dictates.

It is obvious from this schedule that the entire research program is dictated by the initial choice of decision support tools. This is no different, however, from saying that any research program is dictated by the choice of the objectives of the program. We believe that the research program *should* be organized around the production of management tools, and that this choice should play a major role in determining the future of the research. However, the diversity of individual research projects within the program should provide ample opportunity for shifts in emphasis and the replacement of one tool by another as new ideas and methodologies are developed.

Building on this sequence of activities, we suggest the following sequence of work starting on January of 1989.

- Evaluate the research strategy recommendations.
- Review current and proposed projects in light of the recommendations accepted.
- Initiate new projects to fill data and knowledge gaps that are identified (see below).
- Review existing competition assessment methodologies, and select a candidate methodology for initial development as a prototype field assessment methodology.
- Review existing computer simulation models and select candidate models. Test and demonstrate the models' capabilities and deficiencies. Initiate the necessary development of the models to correct unacceptable deficiencies.
- Review existing "expert system" types of decision support systems, and select a candidate approach. Identify the data base required by this approach and initiate the assembly of a prototype data base from existing research results and operational field experience.
- Develop research protocols for assessment research, prediction research, management treatment, and impacts research.
- Review existing management, RX and SX trials, and the results of past trials, and extract data needed for the development of the decision support tools.

- Continue existing research projects, and expand them where funds permit, according to the research strategy recommendations.
- Identify sites for, and carefully plan, a series of long-term permanent sample plots.
- Develop, test and demonstrate the simulation models.
- Test and demonstrate the assessment methodologies, and further develop these.
- Test and demonstrate the "expert system" decision support tools, and further develop these.
- Initiate long-term permanent sample plots with pre-logging monitoring.
- Summarize existing research results, and conduct detailed interview survey to capture operational field experience. Enter the results in the "expert system" data base.
- Initiate training programs for the users of the decision support tools.
- Continuation of existing research projects.

POSTSCRIPT

In the past, conventional, reductionist research has provided little guidance to forest managers. There is an urgent need in forestry for a systems approach designed to deliver the results of scientific research to forest managers in a simple, useable form (see arguments in Kimmins 1986, and Baskerville 1986), and this is certainly true in vegetation management. This report has recommended that vegetation management research in the southern Interior be established on such a systems basis. The research strategy suggests the means to do this.

Because of a lack of adequate knowledge, many field foresters do not understand the systems-based tools available to assist them in management decision-making. The success of this research strategy will depend to a considerable extent on the success with which the resistance to new ideas and new approaches can be overcome. Wise, informed choices will depend on foresters and research managers being well informed about the options that are available to them.

Finally, forest regeneration decisions *must* consider the implications of other factors, such as climatic change, for regeneration strategies. It is pointless to select a regeneration strategy for a particular area if the climate there will change over the next rotation in a way that invalidates that strategy. The southern Interior includes several areas for which ecologically significant climatic change may be expected over the next 40 years. This issue must be addressed in the implementation of the research strategy, even though it is not dealt with explicitly in the report.

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APPENDIX 1. Copy of questionnaire sent out to 120 forest resource managers and researchers in the southern Interior, November 1987

Vegetation Management Research Questionnaire

Your responses to the following questions will assist in the identification of research priorities for Vegetation Management in the southern Interior of British Columbia. Individual responses will be confidential.

1. In which climatic region of the southern Interior of British Columbia is most of your work conducted?

   [ ] Dry.
   [ ] Moist.
   [ ] Wet.
   [ ] Other location. (please specify) .....
   .....

2. What is the focus of most of your work activities? (please check one)

   [ ] Forest management.
   [ ] Range management.
   [ ] Wildlife management.
   [ ] Research. (please indicate primary field of research) .....
   .....
   [ ] Other. (please explain) .....
   .....
   .....

3. Do you feel that existing research information is being fully utilized in operation vegetation management?

   [ ] Yes.
   [ ] No. (Please explain) .....
   .....
   .....
   .....

4. Which of the following would you find most useful for learning about new research findings or new techniques in vegetation management? (Please rank them from 1 (most useful) to 6 (least useful).)

   [ ] Technical conferences.
   [ ] Courses, training sessions, or workshops.
   [ ] Printed research reports.
   [ ] Printed field guides or handbooks.
   [ ] Field demonstrations and field trips.
   [ ] Informal discussions.
   Comments:

5. The following have been identified as key areas for Vegetation Management Research in B.C. Please rank them from 1 (greatest need) to 5 (least need) based on your own awareness of research needs in your area and field of interest.

[ ] Screening trials to evaluate the effectiveness of vegetation management techniques.
[ ] Environmental impacts of vegetation management techniques.
[ ] Development of operational methods for assessing levels of competition and interference between crop trees and weed species.
[ ] Prediction of vegetation development (succession) following harvesting, site preparation, and vegetation management treatments.
[ ] Economics of vegetation and forest management activities.

Comments:

6. In which vegetation complex do you feel there is the greatest need for further research? (please select only one)

[ ] Pinegrass.
[ ] Alder and Alder - Pinegrass.
[ ] Aspen and mixed hardwood (birch, aspen, cottonwood).
[ ] Mixed shrubs and herbs (thimbleberry, raspberry, fireweed).
[ ] Ericaceous shrubs (Rhododendron, false azalea).
[ ] Subalpine herbs (mountain Valerian).
[ ] Floodplain communities.
[ ] Domestic communities.
[ ] Other (please specify) .....
.....

Comments:

7. In which biogeoclimatic zone do you feel there is the greatest need for further research on forest regeneration and regeneration problems? (please select only one.)

[ ] Ponderosa Pine Bunchgrass zone.
[ ] Interior Douglas Fir zone.
[ ] Interior Cedar Hemlock zone.
[ ] Montane Spruce zone.
[ ] Sub Boreal Spruce zone.
[ ] Engelmann Spruce Subalpine Fir zone.

8. Which of the following kinds of tools would you find useful for predicting or assessing vegetation management problems, and for developing site prescriptions? (please rank them from 1 (most useful) to 5 (least useful))

[ ] Technical experts.
[ ] Field guides or handbooks.
[ ] Computer (microcomputer) simulation models.
[ ] Computer (microcomputer) assisted decision support systems (e.g. "expert system").
[ ] Other (please explain) .....
.....
.....

9. Would you be willing to answer additional questions (by phone or mail)? (please check one)

[ ] No.
[ ] Yes. (please complete the following)
Name: .....
Address: .....
.....
.....
.....
Telephone: ( ) _____ - ____

Thank you for taking the time to respond to this questionnaire.

If you have any additional comments please feel free to append them to this questionnaire.

Please return the completed questionnaire before December 15 1987 in the postage paid envelope provided.

APPENDIX 2. List of Latin and common names of species referred to in the text

Common Name	Latin Name
black cottonwood	*Populus balsamifera* L. ssp. *trichocarpa* (Torr. & Gray ex Hook.) Brayshaw
black huckleberry	*Vaccinium membranaceum* Doug. ex Hook
black twinberry	*Lonicera involucrata* (Richards.) Banks ex Spreng.
blueberries	*Vaccinium* L. species
bracken fern	*Pteridium aquilinum* (L.) Kuhn
devil's club	*Oplopanax horridus* (Smith) Miquel
Douglas maple	*Acer glabrum* Torr. var. *douglasii* (Hook.) Dippel
elderberry	*Sambucus racemosa* L.
false azalea	*Menziesia ferruginea* J.E. Smith
falsebox	*Paxistima myrsinites* (Pursh) Raf.
fireweed	*Epilobium angustifolium* L.
green alder	*Alnus incana* (L.) Moench ssp. *tenuifolia* (Nutt.) Breitung
ladyfern	*Athyrium filix-femina* (L.) Roth.
lodgepole pine	*Pinus contorta* Doug. ex. Loud var. *latifolia* Engels
mallow ninebark	*Physocarpus malvaceus* (Greene) Kuntze
ocean spray	*Holodiscus discolor* (Pursh) Maximowicz
paper birch	*Betula papyrifera* Marsh
pinegrass	*Calamagrostis rubescens* Buckl.
raspberry	*Rubus idaeus* L.
red-osier dogwood	*Cornus sericea* L.
reedgrass	*Calamagrostis canadensis* (Michx.) Beauv.
salmonberry	*Rubus spectabilis* Pursh
Sitka alder	*Alnus viridis* (Chaix) DC. ssp. *sinuata* (Regel) Love and Love
Sitka mountain valerian	*Valeriana sitchensis* Bong.
snowbush	*Ceanothus* L. species
snowbush ceanothus	*Ceanothus velutinus* Doug. ex Hook.
soopolallie	*Shepherdia canadensis* (L.) Nutt.
spiny shield fern	*Dryopteris assimilis* Walker
subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
thimbleberry	*Rubus parviflorus* Nutt.
trembling aspen	*Populus tremuloides* Michx.
vine maple	*Acer circinatum* Pursh
waxberry	*Symphoricarpos albus* (L.) Blake
white-flowered rhododendron	*Rhododendron albiflorum* Hook.
willow	*Salix* L. species
wood rush	*Luzula* DC. species